ECLECTIC EDUCATIONAL SERIES

AN ELEMENTARY GEOLOGY

DESIGNED ESPECIALLY FOR THE INTERIOR STATES

BY

E. B. ANDREWS, LL.D.

Of the Ohio Geological Corps, and late Professor of Geology in Marietta College

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TO

Leo Lesquereux,

THE COUNTRYMAN AND FRIEND OF AGASSIZ, WHO, BY
HIS INVESTIGATIONS OF FOSSIL PLANTS, IN
THE LAND OF HIS ADOPTION,
HAS ATTAINED SUCH
PREËMINENCE AND HONOR,

This Volume is Respectfully Dedicated.

PREFACE.

The distinctive feature of the following work is its limitations. It is designed for students and readers of the Interior States, and, consequently, for such has its chief references to home geology. The simplicity and regularity of the geological formations in these states render them singularly fitted to be illustrations of the science; and, moreover, the formations are rich in fossils beyond those of most other parts of the world. By thus limiting the scope of the work, it is believed that a much better book for beginners may be made than if far more were attempted. No work, however large, can fully set forth a science to which, for the last forty or fifty years, contributions have been made by hundreds of earnest workers in the Old World and the New. The problem has been to give enough, and that clearly, and not too much.

The district chosen is one in which the author has spent most of his life, and with much of which he is personally familiar. It is a geological field now pretty well worked over. The order of the succession of the rocks in these Interior States has been studied by Mather, Hildreth, Briggs, Foster, Whitney, Whittlesey, Hall, Houghton, Hubbard, Douglass, Owen, Swallow, Shumard, Worthen, the Winchells (A. and N. H.), Pumpelly, Rominger, Broadhead, Cox, Collett, Lapham, Chamberlin, Irving, Strong, Orton, G. K. Gilbert, Read, Shaler, Engelmann, Shaw, Bannister, and many others. The fossils found in these States have been described by Hall, Lesquereux, Meek, Worthen, Whitfield, Nicholson, White, McChesney, Shumard, Lyons, Cope, St. John, Newberry, Scudder, and several others.

Thus it will be seen that the materials are over-abundant, and the question what to omit has ever been the pressing one. The order of the rocks is fully given, but no effort has been made to give the palæontology in an exhaustive way, nor to present the details of classification. The latter is admirably done in the large *Manual* of Prof. Dana. The more difficult and profound questions of geological dynamics have necessarily been left without discussion.

The advanced student will find these treated with ability both in the *Manual* alluded to, and in the work of Prof. Le Conte, recently published.

It has been the desire of the author to present the more important facts in the economical geology of the Interior States. When it is remembered that within these states there are larger areas of coal-fields of the Carboniferous Age than probably exist in all the earth besides; that in these states are the great iron mines of the Lake Superior region and of Missouri, the copper mines of Lake Superior, and the extensive lead and zinc mines of Wisconsin, Illinois, Iowa, and Missouri—the propriety of giving to the economical features of the country a measure of prominence will not be questioned.

Thanks to the generosity of the Publishers—it might be more properly called their wisdom—the author has been enabled to illustrate the work with that fullness demanded in all elementary books on science. Of the four hundred and thirty-two illustrations, probably more than three fourths have never appeared in any text book before. They have been selected from the Geological Reports of the Interior States, and from similar sources of the highest scientific authority. A very considerable number of these are entirely new, having been drawn by the author, or under his immediate supervision. Mr. H. F. Farny has contributed some illustrations of much artistic merit. Such of the figures as are produced by the photo-engraving process, were redrawn from the Geological Reports and other sources—in some cases from original specimens—by Mr. A. Schrader, who made the fine drawings of mosses for the works of the late Wm. S. Sullivant.

The author would make a full and cordial acknowledgment of his indebtedness to the many geologists who have labored in the Interior States. He has made free use of their labors, without which this volume could never have been written; but with which, such a work becomes a necessity.

He would also express his thanks to the large number of teachers and scientific friends, who have approved of the plan of this work, and encouraged him to prepare it as a text book. Nor has the interest in the work been limited to these: kind words have been received from Ex-Gov. J. D. Cox, Gen. J. A. Garfield, Hon. Thomas Ewing, Robert Clarke, Esq., and many other friends of education and progress, who encourage every well-meant endeavor to increase and diffuse knowledge. His gratitude to such is best shown by the effort to make the work worthy of their approval.

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INTRODUCTION.

1. Geology, derived from γη, the earth, and λογος, discourse, is the science which treats of the structure and history of the earth. That structure is seen in the minerals and rocks; and the history is read in the changes which have taken place in them, and in the records of the remains of animals and plants which the rocks contain.

2. Geology is a comparatively recent science. Other sciences must precede it. Mineralogy and chemistry must first determine the nature of minerals and rocks. Physical geography must first show the influence of heat and cold, of winds and currents of water, and trace the phenomena of volcanoes and earthquakes and glaciers. Botany and zoölogy must previously make us familiar with the plant and animal kingdoms. All this, and indeed much more, must be done before the way is prepared to trace back into the geologic Past the workings of those forces, animate and inanimate, which have given to the earth its wonderful history.

3. The General Plan of the Work.—It is proposed to consider Geology with especial reference to the interior portion of the United States, viz.: Ohio, West Virginia, Kentucky, Indiana, Michigan, Illinois, Wisconsin, Missouri, Iowa, and Minnesota, called in our geographies the North Central States.

The plan contemplates a brief survey of the surface features, and a summary of the leading rocks, metals, and ores found in these states. It requires an explanation of the way in which the rocks were formed, and how they have been inclined and changed from their original positions.

The rocks are classified according to their several Formations, and placed in the proper historical order; and their geographical locations are given, and the geological map is explained.

The different Formations are then considered at some length, and the story of the earth is brought down from the earliest records in the rocks to the time of man.

ELEMENTARY GEOLOGY.

CHAPTER I.

SURFACE FEATURES OF THE INTERIOR STATES.

4. THE states referred to in this work lie in the great interior basin of the continent, drained by the Mississippi River. The exceptions to such drainage are the limited areas bordering the Great Lakes; the northern part of Minnesota, which slopes to the north and is drained into Hudson Bay; and that portion of West Virginia lying upon the eastern slope of the Alleghany Mountains, drained by streams flowing into the Atlantic Ocean.

5. **The Great Central Basin** extends north into British America, and to Hudson Bay. If we follow the Minnesota River, a branch of the upper Mississippi, to its head in Big Stone Lake, on the western border of Minnesota, we have only to go six miles beyond to Traverse Lake to reach the head of the Red River of the North. In the spring we can pass from one lake to the other in canoes.

6. **Highest Point.** — Here is the highest part of the bottom of the central basin, or trough; and when a shower of rain falls upon the area between the two lakes, some of the drops of water will find their way into the Gulf of Mexico, and others into Hudson Bay. The map (Fig. 1.) on the next page shows the position of the streams and lakes. This summit is only 1,000 feet above the level of

the ocean, and 398 feet above Lake Superior. It is thus seen that the great central valley has no mountain chain across it. It is simply a trough with a double pitch, just as an eaves-trough might incline at either end, as represented in Fig. 2. It is believed that at one time the summit of the trough was farther north, and that Lake Winnipeg discharged its waters southward through the Red River of the North and the Minnesota River, which were then one continuous stream.

Fig. 1.

The Mississippi River proper rises in higher ground than the Minnesota, in a region of lakes and swamps, west of Lake Superior, about 1600 feet above the sea. The northern part of the State of Minnesota may be called the *central source of waters*, for from it flow streams northward into Lake Winnipeg and Hudson Bay; eastward into Lake Superior, and thence through the Great Lakes and the St. Lawrence into the Atlantic Ocean; and southward into the Gulf of Mexico.

7. **Elevation of Land.**—There are no mountains in the Interior States, except those of the Alleghany range in West Virginia, and the Cumberland range in Kentucky. The Ozark Mountains in Missouri are not properly mountains, but only a broad swell of land, about 1520 feet above the sea. The highest points immediately south of Lake Superior, in Michigan and Wisconsin, are reported to be

1800 feet high. The highest known point in Ohio is in Logan County, 1540 feet above tide water. No land in Indiana or Illinois has an equal elevation. Weed-patch Hill in Brown County, 1147 feet high, is the highest point in Indiana. There are no high lands in the Lower Peninsula of Michigan. In Iowa, the high ground, or divide, between the Mississippi and Missouri rivers, ranges from 1188 to 1694 feet. The longer slope is toward the Mississippi River. In West Virginia, the highest point of land is Panther Knob, in Pendleton County, 4000 feet high. This is in the Alleghany Mountain range.

Fig. 2.

8. Drainage.—A glance at a map will show the drainage system of the Interior States. It will be seen that the streams flowing into the Lakes are generally short and small. The water-shed, *i. e.*, the highest land from which the water flows down the opposite slopes, is generally quite near the Lakes. In Ohio, the larger streams flow southward into the Ohio River. The Maumee River is the chief exception. In north-western Indiana, in Laporte County, the water-shed is eleven miles from Lake Michigan, and only 270 feet in elevation above the lake. In Illinois, so low is the water-shed that at Chicago a canal has been excavated through it to carry the water of the Chicago River back into one of the branches of the Illinois River. It is an interesting fact that one of the head streams of the Ohio River rises in Chautauqua Lake, in western New York, only seven miles from Lake Erie. This lake is 737 feet above

the level of Lake Erie. The water flows down the Alleghany River into the Ohio, but does not descend to the level of Lake Erie until it reaches a point a few miles below the mouth of the Muskingum River. This shows how idle is the often proposed project of making the upper Ohio navigable, in times of low water, by a canal from Lake Erie to Lake Chautauqua to bring the water of the former into the latter, and thence into the Ohio. The relative levels of the two lakes are shown in Fig. 3.

Fig. 3.

9. Elevations of the Great Lakes.—The following is a table of the elevations of the Lakes above the sea-level, and also of the depths of the water in them:

	Elevation.	*Depth.*
Lake Superior, . . .	602	1000.
" Michigan, . . .	582	900.
" Huron, ...	582	750.
" Erie, ...	573	204.
" Ontario, ...	247	606.

The relative elevations and depths are shown in Fig. 4.

10. Water Discharge of the Interior Rivers.—The average discharge of water from the Ohio River, for each second of time, is 158,000 cubic feet; from the upper Mississippi, 105,000; and from the Missouri, 120,000; in all, 383,000 cubic feet. This water comes from rain and melted snow. Much is evaporated from the surface, and carried by winds beyond the limits of these river basins, so as not to return again in the form of rain.

In the Ohio and upper Mississippi basins, only 24 per cent. of the water falling upon the surface passes out of these rivers; and of the rain in the Missouri basin, only 15 per cent.

The Ohio basin contains an area of 214,000 square miles; the upper Mississippi, 169,000; and the Missouri, 518,000.

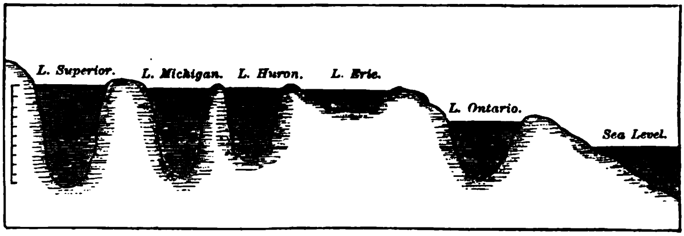


Fig. 4.

11. Prairies.—An interesting surface feature of many of the Interior States is the prairies. Some of these are very level, while others are quite undulating, or, in Western phrase, "rolling." Before settlement by Europeans, they were all treeless except along the margins of streams.

The absence of trees from prairies has been attributed to various causes: to the want of sufficient moisture in the soil and atmosphere; to the annual prairie fires; to the fineness or powdered condition of the soil; and to the preoccupation of the soil by grasses. In all the Interior States trees thrive, when properly planted and protected.

12. Drift.—The prairies and the northern portion of the Interior States are covered with a mantle of comparatively loose materials—sand, clays, and bowlders—commonly called *drift*, because they were brought or drifted from a region more or less distant. This over-spread of drift is often so thick that the rivers flow upon it, although some of the larger ones have channels deep enough to cut down into the stratified rocks which underlie the drift. The

upper Mississippi River is generally bordered by rock-ribbed hills, and so is the Ohio.

13. **Channels.**—The course of every large stream, like the Ohio, was at first determined by a depression in the earth's surface, causing the stream to flow in it towards its lower end. The water slowly wore out for itself a deep channel. The tributary streams, flowing down either slope of the great valley, wear their channels, and these have their branches; and so on, smaller and smaller, until we find a system of water courses much resembling a tree with its branches and twigs, as shown in Fig. 5.

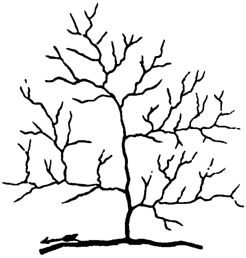


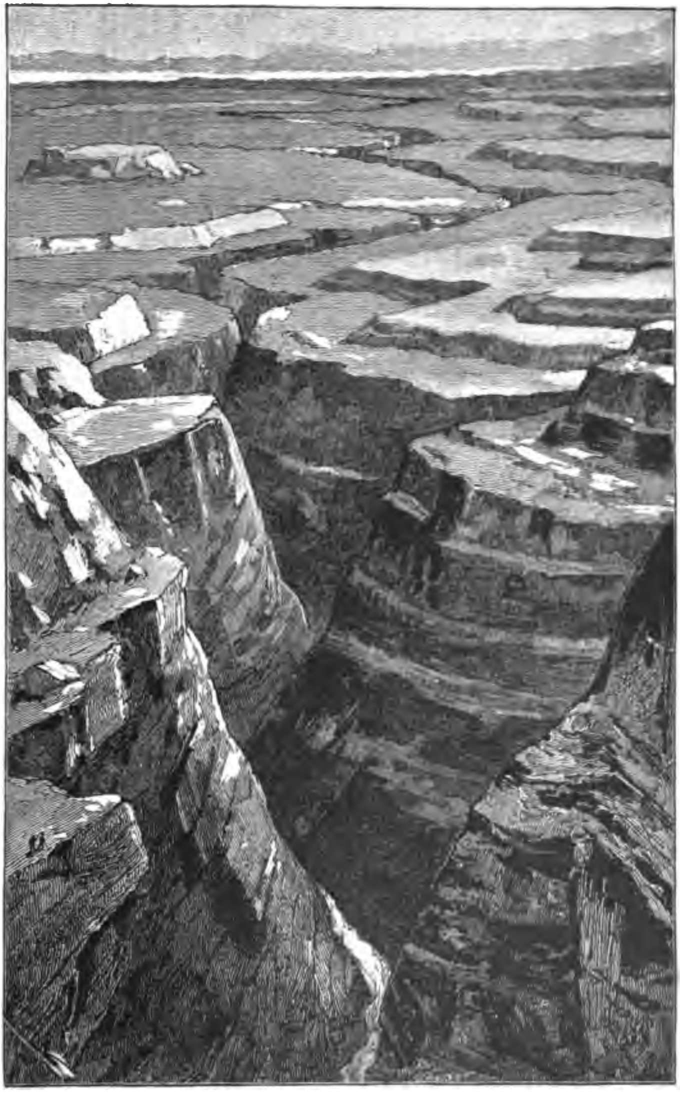
Fig. 5.

14. **How hills are generally formed.**—Unless the rock formation is very hard, the region drained by these streams is carved by the water into rounded hills and valleys. It is the work of the water that falls upon the surface. No great sweeping currents of water, nor moving glaciers could wear out deep valleys running in all possible directions. If we give the rains time enough, they will do all this beautiful carving.

In a desert region, where no rain falls upon the surface, the rivers flowing through it, having derived their water from the rains and melting snows of distant mountains, will cut for themselves deep rock channels, with almost vertical walls. Such a channel is the famous Colorado Cañon, a portion of which is shown in Fig. 6, page 17.

The depth of this cañon is in some places nearly 6000 feet, measured from the tops of the bordering cliffs. A few years since, Maj. J. W. Powell with a small party passed down this cañon in small boats, and had a very rough time of it among the rocks and water falls.

Fig. 6.



Grand Cañon of the Colorado River.

If, in this region, rains had fallen, as in the Ohio basin, we should have had innumerable lateral valleys, bordered by high and beautiful hills.

15. **Hills half removed.**—We sometimes, indeed, find the Ohio and other streams in the Interior bordered by cliffs, but these are quite often old rounded hills, with one side cut away by the streams. Such cliffs are seen at Buena Vista, Ohio, and in the Kentucky hills opposite Portsmouth (the latter shown in Fig. 7), and at many points on other rivers.

Fig. 7.

16. **Terraced hills.**—We often find the hills terraced. This is quite common in our coal fields in Ohio and West Virginia. The explanation is simple. The rock strata in the hills are of different degrees of hardness—soft shales alternating with hard sandstones or limestones. Such terraces are represented in Fig. 8. Here *a*, *a*, *a* are soft shales, which under the action of the weather are gradually softened and removed, while *b*, *b*, *b*, *b* are hard sandstones, which, when undermined by the removal of the shales, break off, leaving vertical ledges, as shown in the figure.

Such terraces may often be traced for many miles, perhaps on both sides of a valley. If the shales contain a seam of coal, as they sometimes do, we may know where to find the coal by a careful tracing of the terraces. These

Fig. 8.

terraces are properly *rock* terraces, although generally covered with more or less soil, and must not be confounded with the sand or gravel terraces which skirt the streams in the valleys. The latter were formed by the water when it flowed at higher levels than at present.

17. **River beds.**—As a general rule our streams flow in channels above their old rock beds, now buried by sands and clays. Such an elevated river bed is seen in Fig. 9. *A* is the present river bed, but in former ages the stream has flowed over the bed-rock below.

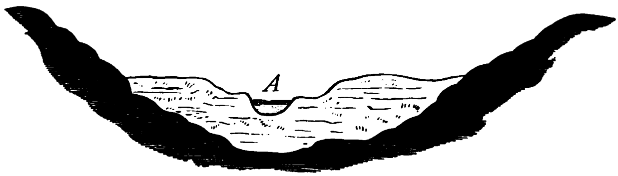


Fig. 9.

18. **Wandering rivers.**—Sometimes a river, in wandering from side to side in its filled up, old channel, gets

upon a marginal bench of hard rocks. This is represented in Fig. 10. Here the Ohio River is making a new rock channel for itself, while the old and deeper one is on one side. This is said to be the state of things at Louisville, Ky., where the river makes a bend from its direct course and passes over the limestone rocks at the falls, while the old deep channel is buried under the terrace on which the city is built.

In many cases, perhaps in most, the streams, passing from such marginal rock benches into the ancient channels below, find a lower level, and thus rapids, and sometimes falls, are produced.

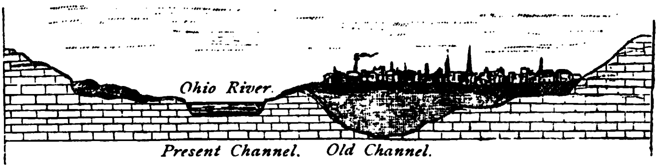


Fig. 10.

19. The widening of valleys.—While the beds of the rivers are not now becoming deeper, except at a few points, the process of widening the valleys is still going on, for we frequently see the rivers washing the bases of the adjacent hills, and undermining the rocks. This is a slow process, but it is seen in operation in nearly all valleys. When the strata in the hills are composed of soft materials, like shales, the process is more rapid; and valleys eroded in such shales are always much wider than those cut out of harder rocks.

In valleys, like that of the Missouri River, the stream forms ox-bow curves, which, in time, are cut through at the necks of the bends, and the stream becomes straight again, leaving semi-circular or crescent-shaped ponds in the aban-

Fig. 11.

doned channel-ways. If the alluvial valley is wide, the stream may thus straighten itself before it reaches the bordering hills and bluffs. In narrower valleys, the streams frequently reach the bases of the hills, and undermine the rocks.

Fig. 11 represents a stream at work widening a valley as it wanders from cliff to cliff.

CHAPTER II.

ROCKS AND ORES OF THE INTERIOR STATES.

20. **Rocks.**—The term rock includes all minerals and combinations of minerals, whether hard and compact as granite and marble, or soft and loose as clay and sand. The latter were derived from solid rocks, and may in turn become such.

(1) SANDSTONE.—This is a rock formed of sand. The sand was deposited in beds along banks and shores of ancient rivers and oceans. When pure, sandstone is made up of grains of quartz. This kind is used for making glass. When it contains a little clay, and works freely under the stone-mason's chisel, it is sometimes called a *free-stone*, and is used as building stone. When composed of gravel, it is called *conglomerate* or pudding-stone. Sandstones are sometimes almost white, and sometimes reddish brown; but the more common color is a grayish brown. Sandstones are found in all of the Interior States.

(2) SHALE is a soft, fine-grained rock, made up of layers. It was formed of mud, and is sometimes for this reason called *mud-rock*. If the mud contained some sand, the shale is a *sandy* shale; if formed chiefly of clay, it is a *clayey* shale; if it is black and contains bituminous matter, the product of decayed plants and animals, it is called *bituminous* shale. All shales are bedded in layers. When

a shale is hard and firm, and splits into thin even sheets, it is called slate; and *school* and *roofing* slates are made of it.

(3) Fire Clay is a fine pure clay, not slaty like other mud-rock, and is used for making fire bricks and tiles.

(4) Limestone is a rock composed of lime and carbonic acid. When we burn limestone to make quicklime for mortar and whitewash, etc., the carbonic acid is driven off by the heat in the form of a gas. Pure limestone is called *calcite*, and often occurs in crystals. Ordinary limestone contains impurities, chiefly clay and sand. *Chalk* is a soft limestone. *Marble* is a hard, crystalline form of limestone. It is more durable than common limestone, and takes a high polish. *Hydraulic* limestone contains portions of magnesia, silica, and clay, and from it is prepared a cement that hardens or sets under water. It is sometimes called water-lime, and is used in plastering cisterns, and laying the piers of bridges, etc.

When limestone contains considerable magnesia, it is called a *magnesian* limestone or *dolomite*. A clay containing a large amount of carbonate of lime is called *marl*. Shells often make up a large part of marl.

(5) Gypsum is a combination of lime and sulphuric acid. It is used in the arts for stucco work and for casts of statues, and also as a fertilizer of the soil. A common name for gypsum is plaster of Paris.

(6) Celestite is a bluish white mineral, composed of strontian and sulphuric acid. Fine specimens of crystallized celestite are found on Strontian Island, in the western part of Lake Erie. Strontian is used in fire works to make a red light.

(7) Barite, or heavy spar, is a very heavy white mineral, used in the arts, and often to adulterate white lead paint. It is found in Iowa, near Fort Dodge; in Kentucky, at Paris; and at other points in the Interior States.

(8) GRANITE is a crystalline rock, composed of quartz, feldspar, and mica.

(9) QUARTZ is a hard mineral, transparent when in pure crystals, and looking like clear glass. It scratches glass and steel, and it is the grains of quartz in sandstone that make it desirable for grindstones. Grains of quartz glued upon paper form sand-paper. Quartz is found in many forms. Amethyst, agate, chalcedony, jasper, flint, hornstone, chert, etc., belong to the quartz family. The term *silica* is sometimes used for quartz.

(10) FELDSPAR is less hard than quartz, splits into plates, and has a pearly luster. It is generally white, or of a very light red color. It forms, when decomposed, the kaolin used in pottery.

(11) MICA is a bright shining mineral, in flat sheets or plates, which may be split into layers as thin as tissue paper. It is often as transparent as glass, and is sometimes used for it. It is frequently called isinglass, but improperly.

(12) GNEISS (pronounced *nice*) has the same elements as granite, but it is in layers, and the rock can be split into slabs, and in this respect differs from granite.

(13) MICA SCHIST is like gneiss, except that it is of finer texture, and more laminated—splitting more readily, and into thinner layers. It also contains more mica. *Mica slate* is generally used to designate a mica schist of fine texture, with the mica less distinct; but the two terms are often used interchangeably.

(14) SYENITE.—This rock is like granite, but it has hornblende in place of mica. The *hornblende* is a brittle mineral, generally quite dark in color. The Quincy granite, used largely as a building stone in Boston, is syenite. The red Scotch granite, imported into this country for monumental purposes, is also syenite.

(15) COAL may be classed with our rocks. It originated from vegetable matter, as some of our limestones did from shells, corals, etc. *Bituminous* coal is the only kind in the Interior States. *Anthracite*, a kind of coal from which the bitumen has been removed, is found abundantly in Pennsylvania.

(16) TRAP ROCKS.—Trap, sometimes called *basalt*, is a dark colored, greenish, brownish, or black rock, which was once in a melted state. Rocks of this kind are found in the Copper district of Lake Superior; on the Hudson River, where they form the Palisades; in the Connecticut River valley; and on the Pacific slope of the Rocky Mountains.

Sometimes almond-shaped cavities were formed in the trap, which were afterwards filled with other minerals, often beautifully crystallized. This is called *amygdaloidal* trap, from the Latin word, *amygdalum*, an almond.

Trap is sometimes called *melaphyre;* it is also called *dolerite.*

21. Metals and Ores.—The metals and ores may be divided into two classes, *Precious Metals* and *Inferior Metals.*

Precious Metals.

(1) GOLD has been found, in small quantities, in the Drift sands and clays of Ohio, Indiana, and Missouri, and probably can be found, in similar deposits, in all the Drift region.

(2) SILVER is often found with the native copper of the Lake Superior region, generally in threads and small specks. It is not alloyed with the copper. *Ores* of silver are also found. Some of the galena, or lead ore, contains it, and is then called *argentiferous*, or silver-bearing, galena.

The most famous locality for silver ore in the Lake Superior district is Silver Islet, a very small island north of Isle Royale. Very large veins of silver ore are found in the far West, the most remarkable and productive being in Nevada.

Inferior Metals.

(1) COPPER.—Metallic, or native, copper is found associated with the trap rocks of the Lake Superior region. Ores of copper are also found, the more common being *copper pyrites*, composed of copper and sulphur.

(2) LEAD ORES.—*Galena*, or *galenite*, is the usual ore of lead. It is of a bluish lead color, and breaks easily into cubes with sharply-defined edges and corners.

This ore is formed of lead and sulphur—86.6 per cent of the former, and 13.4 per cent of the latter. The sulphur is readily driven off by heat, and the ore is easily smelted.

There is an extensive lead ore district in north-western Illinois, south-western Wisconsin, and north-eastern Iowa. Galena is also largely mined in Missouri, and to a less extent in southern Illinois and western Kentucky.

Cerusite, white lead ore, is a carbonate of lead, composed of 83.5 per cent of lead, and 16.5 per cent of carbonic acid.

(3) ZINC ORES are often associated with those of lead. *Smithsonite* is a carbonate of zinc, called "dry bone" by the miners. *Calamine* is a hydrous silicate of zinc. *Blende* (*sphalerite*) is a combination of zinc and sulphur. All of these ores of zinc are found in the lead producing districts of the Interior.

(4) IRON ORES.—These abound in many of the Interior States. *Magnetic iron ore* (*magnetite*), when pure, contains 72 per cent of iron. Its powder is black. *Specular ore*, or *red hematite*, with a red powder, contains 70 per cent of iron. *Limonite* (*brown hematite*), with a brownish, yellow powder, yields, when pure, 60 per cent of iron. The above ores are oxides of iron. *Siderite*, a carbonate of iron, yields 48 per cent of iron. This is the clay ironstone of the Coal-measures.

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CHAPTER III.

How Rocks are Formed.

Having, in Chapter II, noticed some of the leading rocks in the Interior States, we shall now inquire into the history of these rocks, and learn how they have been formed.

22. **Three classes of rocks.**—Rocks may be divided into three classes, viz.: *sedimentary*, such as shales and sandstones, formed of sediments moved and deposited by the action of water; *organic*, such as coal, formed of buried vegetation; and *igneous*, which, like trap, were once in a melted state.

23. **Sedimentary rocks**, or rocks formed from the waste of older ones.—After a hard rain, we can see mud and sand in every little brook or run, moving down with the water. These smaller streams empty into larger ones; and so, in time, the mud and sand reach the Mississippi, and at last the Gulf of Mexico. The Ohio is always muddy when the water is high, and the Missouri is muddy at all times. There is mud enough carried down the Mississippi River every year to cover 241 square miles one foot deep. This would bury with mud 154,240 acres. Besides this quantity of floating mud, the river pushes along its bed enough sand to bury 27 square miles, or 17,280 acres; making of mud and sand together a quantity sufficient to bury 171,520 acres, or 1715 farms of 100 acres

each, to the depth of one foot. At this rate there would be enough mud and sand carried down in thirty years to cover an area equal to the whole surface of Massachusetts.

24. Origin of the mud and sand.—Whence comes all this mud and sand? They come from the rocks of the great valley. Let us see how. If we go among the hills, we shall see the solid rocks slowly yielding to frosts, rains, and winds. The surface of the sand-rock, where exposed to the weather, softens; the grains of sand are loosened, and are washed off by the rains or are blown away by the winds. Shales and clayey rocks are more readily softened, and with water form mud, which the rains and streams carry away.

In Fig. 12, we see a ledge of sandstone and shale, which is slowly acted on by the weather. The little stream at its foot is the porter to carry away the sand and clay.* Often fragments of solid

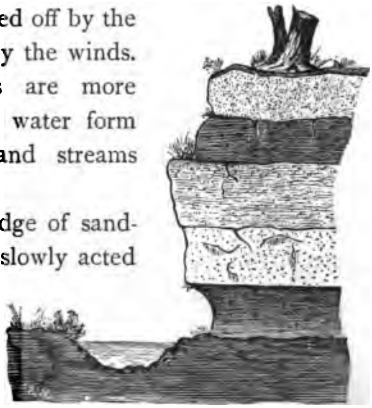


Fig. 12.

* NOTE.—According to Mather, a stream with the velocity of

3 inches per second wears away fine tough clay;
6 inches per second removes fine sand;
12 inches per second removes gravel;
24 inches per second removes pebbles one inch in diameter;
36 inches per second removes angular fragments two to three inches in diameter.

Rocks lose nearly one third of their weight in water. The mathematical rule is that the transporting force varies as the 6th power of its velocity; *i. e.*, doubling the rate increases the force 64 times. If a stream moving 10 miles per hour would move a stone weighing one ton, one moving 20 miles per hour would move a stone of 64 tons.

rock are broken from such ledges and fall into the streams, which carry them off in times of freshets. They go rolling and grinding upon each other until they are rounded and worn into pebbles, then into gravel, and then into sand. Shales are worn into mud. The harder the rock, the longer the fragments last. Lumps of soft bituminous coal do not last very long. The sharp corners and edges are first broken off; the pieces become rounded, and roll like balls until they are entirely wasted away. Flint, quartz, granite, trap, etc., are much harder, and require long continued wearing to become rounded and reduced in size; but, in time, the hardest rocks are worn down to gravel and sand. Fig. 13 shows the effect of wear upon stones; *a* is an

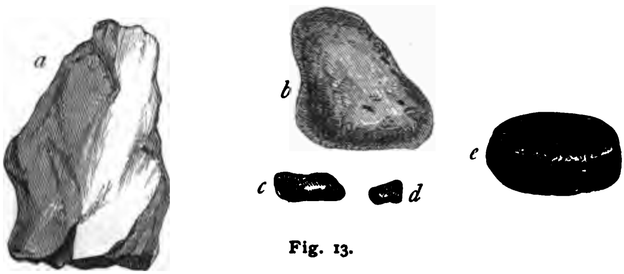


Fig. 13.

original angular fragment; *b*, *c*, and *d* are reduced forms: *e* is a small ancient pebble of coal found in a sand-rock.

25. **Water and Spray.**—In sandstone regions the streams have cut deep valleys, with cliffs on either side. Following up such a valley, we often find it terminating in a curved cliff, over which the little stream makes a fall. Under this fall is a deep recess—a sort of cave, as shown in Fig. 14, page 30. The walls of this cave are generally dry; but when the water is high, the spray of the fall is driven against them. The wetting and drying, with the aid of frost, gradually waste the rock, and the particles

of sand drop down and are carried away by the water. The recess thus formed is generally crescent-shaped. The overhanging rocks in time break down; the fragments are worn away, and carried off by the stream; and so the valley is formed. If water is the plow which makes the valley, the spray is the point or nose of the plow, which leads the way in undermining the cliff.

Fig. 14.

While the streams are ever busy in eroding valleys, the waves dashing upon the shores of seas and lakes are also constantly at work wearing away cliffs and headlands. See Fig. 15.

Fig. 15.

Glaciers, which are rivers of ice, also grind down the stones in their beds, and leave them as gravel, pebbles, and bowlders in great piles, called *moraines*. Such glaciers are found in the Alps.

26. **Soil.**—The soil and loose earth covering the surface have been derived from wasted rocks. The grains of sand and clay are not always carried away at once by the streams, but remain for a time upon the surface of the hills and in the valleys. But these materials always tend downward to lower levels, so that there is generally a thicker deposit of soil in the valleys than on the hill-sides.

Sometimes the earth on the slopes of the hills is brought down in large masses, called *land slides*, as represented in Fig. 16. They are generally produced by water softening the clays underneath the surface. Such slides are quite common in the hilly portions of the Interior States, but are generally on a small scale. The tendency of soft clay to slide in this way often gives much trouble to builders of railroads.

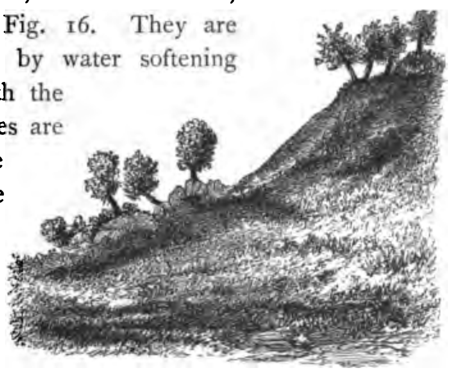


Fig. 16.

The water in the streams is each year carrying away more or less of the loose surface earth. Hence we may consider the soil we cultivate as merely particles of the old rocks, resting for a while on their journey to the sea.

27. **Mud and sand settling in lakes.**—When rivers empty into lakes, the mud they carry settles to the bottom. Hence, all of our lakes are slowly filling up. The beautiful Lake of Geneva, in Switzerland, is not as large as in the days of the Romans. A Roman town, situated upon the shore of the lake, and possessing its little harbor, is now a mile and a half back from the shore, the intervening space

having been filled with mud and sand brought by streams from the mountains. If a large and muddy stream, like the Missouri River, flowed into the upper end of Lake Erie, that lake would soon be filled with mud, and the river would merely flow in a channel through the length of the lake basin.

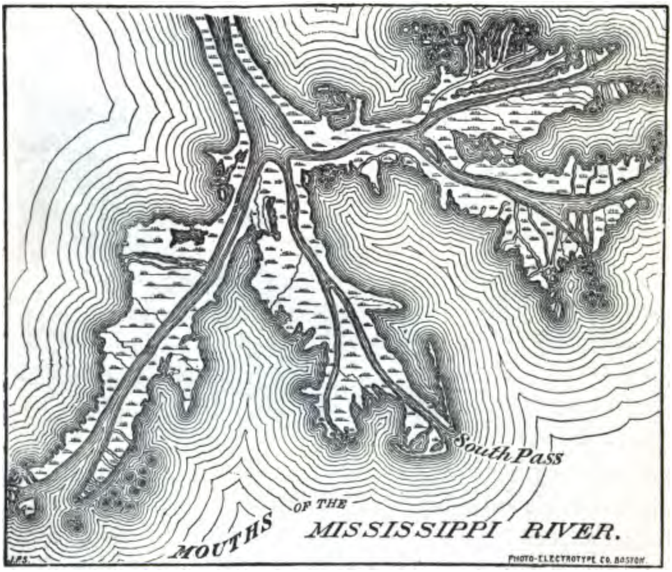


Fig. 17.

28. Deltas.—The formation of deltas—so called from the triangular letter Δ of the Greek alphabet—shows how mud and sand accumulate at the mouths of rivers. Fig. 17 represents the mouths of the great Mississippi River.

The river has pushed its channel far out into the Gulf of Mexico, and, at the end of the main channel, has formed several tongues of land. In each tongue is a smaller channel, called a *pass*. The one named the South

Pass, has recently had its channel deepened by the General Government, so that ships and steamboats may go through it more easily.

Besides mud and sand, the Mississippi River carries into the Gulf drift-wood and plants of various kinds. Sometimes the bodies of land animals, such as horses and dogs, are floated down. To these we must add the bodies of alligators, turtles, fishes, shells, etc. All these things, carried by the river into the Gulf, either sink to the bottom or drift upon the shore, and are buried in mud or sand, commingled with many forms of marine life — the fishes, shells, corals, etc., which live in salt water. The geologist of the future, should the sands and mud, then hardened into sandstone and shale, be lifted up and form dry land, would find in them a very interesting variety of fossils.

29. Distribution of the Sediments.— But let us follow the progress of the Mississippi mud and sand a little further. The mud, floating in the water, is carried farther out into the Gulf than the heavy sand, which is only pushed along the bottom. If the bottom of the Gulf were comparatively level, and there were no disturbing marine currents, there would be spread outward over the bottom, beginning at the mouth of the river, a layer of mud and fine sediment.

Fig. 18.

Over this mud the river current would be constantly pushing forward the sand. This would make two thick layers, a bottom one of mud, and a top one of sand. This is shown in Fig. 18.

But there are currents in the Gulf which disturb this regularity of deposition; and, besides, the current of the river is not uniform, it being stronger in times of high water, carrying the sand out over areas which, in lower water, might again be covered with mud. This would make alternating layers of mud and sand. These layers, when hardened into shales and sandstones, would present exactly the appearance of many of the stratified sedimentary rocks, as we find them in all of our Interior States. Fig. 19 shows such a series of shales and sandstones. *a, a, a, a, a* are sandstones; *b, b, b, b* are shales. The note-books of geologists are filled with outline sketches of such alternating rocks. Near Buena Vista, Ohio, on the Ohio River, the author noted more than 150 layers of sandstone and shale in regular alternation.

Fig. 19.

Some of the layers of sandstone are now quarried, and afford excellent building stone for Cincinnati and Louisville.

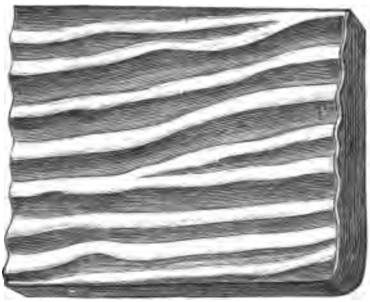


Fig. 20.

30. Impressions in the rocks.—On the surface of these layers, at Buena Vista and at many other places, are impressions of sea-weed, which was drifted by the waters and left upon the original sand. The waves have also

recorded themselves in ripple marks, just as waves are now doing on sandy beaches. Fig. 20 shows such ripple marks, as found in the rocks. What is curious, these marks, found in all the different layers at Buena Vista, have the same direction.*

We often see by the roadside in the country mud which has dried and cracked. These cracks are called *mud-cracks*, sometimes sun-cracks. They are seen on a large scale in the mud-flats in deltas and in bays, where at low water the surface is bare, and dries and cracks from the effects of the sun and wind. When the flats are again over-flowed, sand or mud fills the cracks, and so impressions or casts of them are taken. Such casts are shown in Fig. 21. They are not uncommon in the old rocks of the Interior States. They are sometimes found in limestones in the Coal-measures of Ohio.

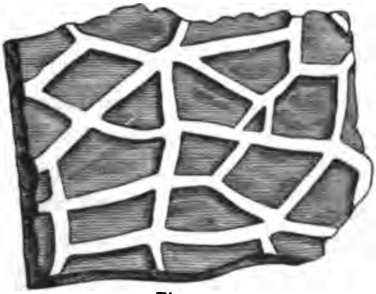


Fig. 21.

Rain drops sometimes make little pits or indentations in soft mud, which remain after the mud hardens. Such impressions of rain drops are also found in the old rocks, as shown in Fig. 22. 79.

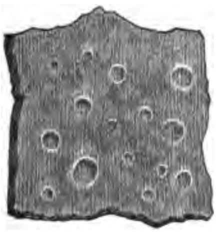


Fig. 22.

* NOTE. — The direction is north 50° west, or nearly north-west and south-east. The prevailing winds must therefore have been at right angles to this line, *i. e.*, from south-west or north-east, doubtless the former, that being the prevailing course of the wind now in that latitude.

Tracks of reptiles in mud, now hardened into rock, are found in the valley of the Connecticut, and elsewhere. Such tracks are shown in Fig. 23.

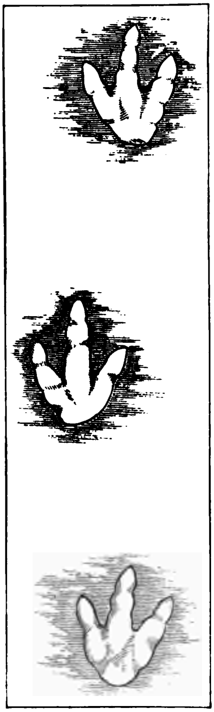


Fig. 23.

All these impressions show plainly that the rocks containing them were once in a soft and forming state.

The beds of sand, gravel, and mud, such as are now being deposited in the Gulf of Mexico, at the mouth of the Mississippi River, when hardened into rocks, as they will be in time, and raised above the water, will form what we call *Sedimentary Rocks*. The sand will become sandstone; the gravel, conglomerate; and the mud, shale—just exactly such rocks as we now find abundantly in the Interior States.

31. Formation of limestones.—Many water animals, such as mollusks, corals, crinoids, etc., take lime from the water to form a solid covering or support. When the animals die, the shells and hard parts remain. These are washed upon the shores, and are often ground to powder, which, forming mud, is carried into more quiet water and settles to the bottom, and in time hardens into limestone.

Sometimes the shells, corals, etc., forming the limestone, are only partially broken, and sometimes, indeed, they are neither broken nor worn. In Florida, there is a rock along the coast called *coquina*, which is a mass of half-broken shells, cemented together. In this way very large

bodies of fossiliferous limestone have been made in the past history of the earth.

There is also a class of very minute animals, called *Foraminifers*, which live in the water, and form tiny shells of lime; these shells sink to the bottom in such vast numbers as to cover it with thick beds of whitish mud, and this mud in time hardens into *chalk*. The white chalk cliffs of Dover, England, are so high that they can be seen from the French coast, twenty-five miles away. These white cliffs gave the name Albion to England, from the Latin word *alba*, white. Chalk is only a softer kind of limestone. Beds of it are found in the Cretaceous formation (from *creta*, chalk) of Kansas. Limestones are generally in layers, like other sedimentary rocks. Where the shells, corals, etc. were ground into fine mud, and this mud was deposited like other muds, we may call the limestone thus formed a sedimentary rock; but a mass of shells or other organic forms, merely cemented together, like many of the limestones about Cincinnati, Ohio, or Burlington, Iowa, is more properly an *organic* rock, a kind of rock to be noticed hereafter.

32. The rocks of the Interior States largely sedimentary.—Such rocks may be seen almost every-where, in the ledges among the hills, and on the rocky banks of thousands of streams. The oldest known rocks (the Archæan) are stratified sedimentary rocks, and were therefore formed of the waste of rocks older than themselves. All our rocks, where exposed, are slowly wasting away from the effects of frost, rain, and running water; and the rivers are carrying them in grains and particles to the sea, to form new rocks, as other streams in former days had gathered the same materials to form them. And this work of rock-wasting and rock-making has been repeated many times.

"My heart is awed within me, when I think
Of the great miracle that goes on
In silence round me—the perpetual work
Of Thy creation, finished, yet renewed
Forever."

There may be forming at different places, but at the same time, the several leading kinds of sedimentary rocks. Soundings in the Gulf of Mexico, from the mouth of the Mississippi River to Key West, show at one place sand, at another, ordinary mud, and at a third, lime or chalky mud—the several materials of sandstone, shale, and limestone. We find among the rocks of the Interior many illustrations of the same thing. If, for example, we follow the Pomeroy, Ohio, seam of coal (the equivalent of the Pittsburgh seam), we shall see in one county a heavy sandrock over the coal; in another county, shales; and in another, limestone. This is represented in Fig. 24.

Different Rocks over the same Seam of Coal.

Fig. 24.

A great many similar illustrations of the changes of sediments might be given.

33. **False-bedding.**—We often find, in the sedimentary rocks, especially in sandstones, examples of what is called *false-bedding*, in which the sand was deposited upon sloping surfaces. It is often seen on sand-bars and in river terraces, as well as in the old rocks. Fig. 25 gives one form of it. Here the stratum *a*, considered as a whole, is a

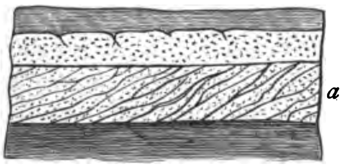


Fig. 25.

regular one, and a part of the series, but at the same time the layers which form the stratum are inclined. Such cases are very common.

34. **Organic rocks.** — Organic rocks are those which are made up chiefly of the organic remains of animals and plants. All plants and animals are organized; that is, they became living and growing bodies through the agency of a force called life. When such forms have lost their life, and have become fossils, we call them organic remains.

COAL is an organic rock, because it is formed of the remains of plants. Leaves of ferns, trunks and roots of trees, seeds and nuts, may often be seen in coal with the naked eye; but with the microscope, nearly the whole of the coal is seen to consist of vegetable matter. Fig. 26 represents a plant from the earlier Coal-measures in Ohio. It will hereafter be shown how seams of coal were formed from the vegetation which grew and accumulated in great swamps or marshes, and was afterwards buried and changed into coal.

Fig. 26.

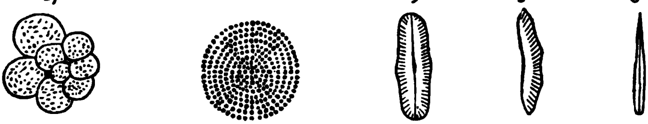
Megalopteris minima.

Some LIMESTONES are composed almost entirely of organic remains — shells, corals, crinoids, trilobites, etc. Some of the limestones about Cincinnati are full of the remains of shells and corals; there are indeed millions upon millions of them. If one should imagine the great heaps of oyster shells near the oyster-packing houses of the Atlantic coast, with all the cavities between the shells filled with smaller

shells and broken bits of coral, and the whole mass cemented together with a limestone cement, he would have some idea of the mass of organic remains in the Cincinnati rocks. Illustrations of many of these fossils will be given in another chapter.

CHALK, as has been previously stated, is chiefly made up of minute forms of animals, which were buried in the ooze at the bottom of the ocean. A common form is seen in Fig. 27, *Globigerina;* this has a lime shell.

27 28 29 30 31



Figs. 27-31.

The other forms, Figs. 28, 29 and 30, have siliceous or flinty shells, and rocks of considerable thickness are formed of such flinty shells.

Many of the rocks of organic origin are arranged in strata, and they often contain so much of the common sediments of sand and clay as to pass into sedimentary rocks. Even coal, by increasing mixtures of mud with the vegetable matter, passes into bituminous shale.

35. **Igneous rocks.**—Igneous rocks are such as were formed of materials brought up, in a melted state, from below the surface of the earth. They are lava, trap, etc. To these may be added the volcanic ashes and cinders, thrown up by volcanoes, and afterwards consolidated into rocks more or less hard.

Volcanoes, from time to time, eject large quantities of melted lava rock, which flow down the sides of the mountains, and fill the valleys and defiles. A volcano in Iceland, in the year 1783, ejected lava enough to fill a valley,

fifteen miles wide and ninety miles long, to an average depth of one hundred feet.

In 1855, there was a great eruption from a mountain in Hawaii, one of the Sandwich Islands. The lava flowed, without noise or earthquake jar, from a point 12,000 feet high, and continued to flow for a year and a half. This lava river was sixty miles long.

Fig. 32.

In Fig. 32, we have a view of the smoke, fire, and boiling lava in the crater of Kilauea, taken from an authentic picture. Miss Sarah Coan states that the great crater is nine miles in circumference, aud one thousand feet deep

below the top of the encircling rim. Within this vast pit is a smaller one still deeper. Within the latter, the lava is constantly in a melted and glowing state. This central pit is called the "House of Everlasting Fire."

The flow of lava is somewhat like that of melted cinder from a blast furnace. The surface cools and hardens, but the pressure of the melted mass within breaks through the crust, and the lava flows down for a time, until its surface in turn becomes cool and hard, to be broken through again; and so the flow is rendered extremely variable. It is reported of a stream of lava, from Mt. Etna, in Sicily, which destroyed fourteen towns and villages, in 1669, before it reached the sea, that, during part of its course, it flowed 1500 feet per hour, and at other times it was several days moving a few yards.

TRAP is a melted rock, somewhat similar to lava, but more compact, which came to the surface through fissures

Fig. 33.

and not through volcanic cones. Sometimes it only filled the fissures, but often it flowed out over the surface of the land, or over the bottom of the sea. When the trap is found in a fissure, it is called a *trap dike.* If the rocks on each side of the dike crumble away, the trap remains as a wall. Sometimes the trap, in cooling, was formed into columns, and the structure is *columnar.* These columns are sometimes horizontal, sometimes vertical, and sometimes radiating.

The famous Giants' Causeway, in the north of Ireland, is an illustration of vertical columns. Another illustration of vertical columns is found in Fingal's Cave, in the Isle of Staffa, in Scotland. A beautiful illustration of radiating columns is seen upon the shore of Lake Superior, as shown in Fig. 33.

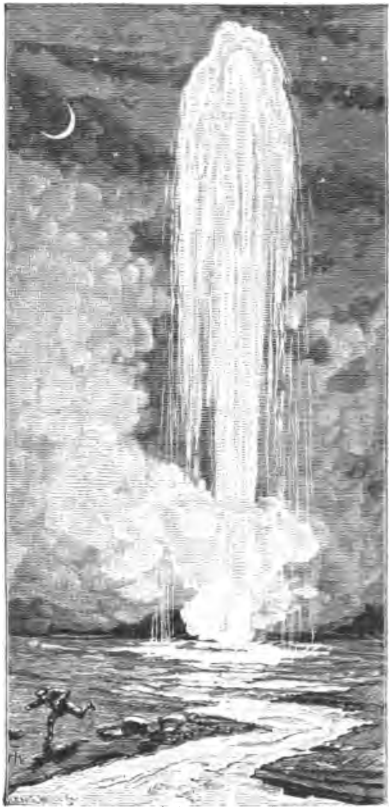


Fig. 34.

36. Hot Springs.— In volcanic regions hot springs are often found, which deposit from their waters more or less silica, and sometimes lime. The geysers of the Yellowstone Park, in the north-west corner of Wyoming Territory, are the

finest in the United States, and probably in the world. Fig. 34 represents one of these, called the Grand Geyser, on Fire Hole River. The orifice is 2 by 4 feet, through which a magnificent column of boiling water is thrown to the height of 200 feet. The eruptions take place at intervals of from 24 to 26 hours, and are accompanied with the rush and roar of vast quantities of steam. There are said to be several thousand hot springs and vents of steam in this region. The U. S. Government has set apart an area of 40 miles square, containing the most remarkable of the geysers, as a National Park. When better roads to it are made, it will be a place of great resort.

The sedimentary and organic rocks described in this chapter, are often greatly changed by heat with pressure. Sandstone thus becomes quartzite; shale, a hard slate; and limestone, marble. Most of the granites are now thought to be changed sedimentary rocks. Anthracite is only a changed form of bituminous coal. All rocks thus changed are called *metamorphic* rocks, the word metamorphic meaning *changed in form.*

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CHAPTER IV.

INCLINATION OF ROCKS.

37. ALL rocks, except those of igneous origin, were, as a rule, laid down in nearly horizontal beds. Sometimes sediments were deposited upon a sloping shore, or upon an uneven sea-bottom, and were thus inclined from the first, but these cases are exceptions to the general rule. When the originally horizontal beds were lifted above the ocean, to form continents and islands, they were not always elevated evenly, by a force acting every-where alike, but unevenly, so that they became inclined, and sometimes curved.

38. **Illustrations of inclined rocks.** — Nearly all the positions in which rocks are found may be represented by books upon a table, as shown in Fig. 35.

The book at *a* lies flat upon the table, and its leaves are horizontal, and well represent horizontal strata. The book at *b* has one end lifted up, and represents rocks with

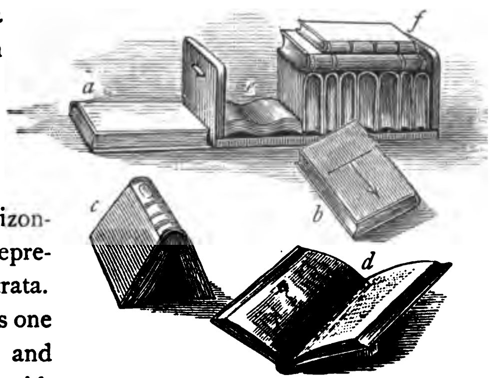


Fig. 35.

a single inclination. Such inclination is called the *dip*, and the angle made by the inclined strata with a level plane is called the *angle of the dip*. If we were to see only the lower end of the book *b*, we might conclude, from the horizontal edges of the leaves, that the leaves were themselves horizontal, which would be a mistake.

If one were in front of the bold cliff represented in Fig. 36, he would think the strata horizontal; but if he were in

Fig. 36.

the cove on the right, he would find them dipping beneath the water.

The direction of the level line of the strata, with reference to the points of the compass, is the line of *strike*, so called from a German word, ſtreichen, to extend. The direction of the line of the greatest dip is at right angles to the line of strike. The line of strike is also the line of *outcrop*.

We often see in the fields inclined rocks, the outcropping

Fig. 37.

edges of the strata, as shown in Fig. 37. The terms strike and outcrop apply not only to strata but to a group of strata making a formation, such as the coal formation.

39. A knowledge of the direction and amount of dip is of great aid to the geologist. If, on a hill, on one side of a valley, there is a seam of coal, we can tell where, on the opposite hill, the same seam is to be found, provided we know the rate and direction of dip, and the distance across the valley.

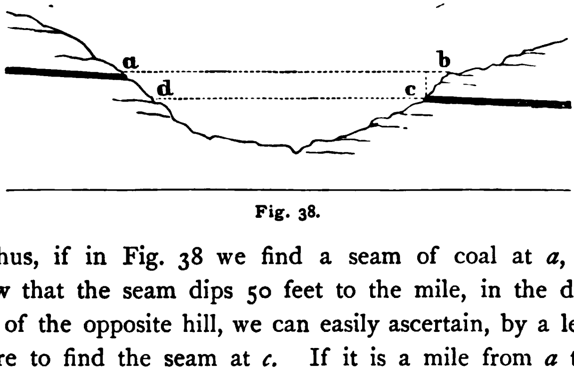


Fig. 38.

Thus, if in Fig. 38 we find a seam of coal at *a*, and know that the seam dips 50 feet to the mile, in the direction of the opposite hill, we can easily ascertain, by a level, where to find the seam at *c*. If it is a mile from *a* to *c*, then *c* will be 50 feet below the level line *ab*. If we were at *c*, we could, by a similar method, find the position of the seam at *a*. If the line of the greatest dip should be to the south, then the dip to the south-east or south-west

would be only half as great. If the first were 50 feet to the mile, the others would be only 25 feet. And, again, a line due east and west would be a level line; that is, the level line is always at right angles to the line of the greatest dip. The arrow on the book *b*, Fig. 35, is the line of the greatest dip, and the line across the arrow is the level line.

40. An anticlinal.—Sometimes strata have a double inclination, as shown by the book *c*, in Fig. 35. The two sides of the book incline in opposite directions. This is called an *anticlinal*, and the back of the book represents an *anticlinal axis*. The ridge of a house would be a similar anticlinal axis.

An anticlinal on a large scale is found in south-western Ohio, extending into Indiana. A cross-section of this anticlinal is shown in Fig. 39. It will be noticed that the rocks dip both ways from the central axis, which is near Cincinnati.

Fig. 39.

41. A synclinal.—Sometimes the strata dip towards each other, or towards a common central line, as shown in the book *d*, in Fig. 35. This combination of strata is called a *synclinal*, from two Greek words meaning to incline towards each other, and the central line is called the synclinal axis. The synclinal is the opposite of the anticlinal: one is V-shaped, and the other is A-shaped.

42. Curved strata.—Again, we may find the strata curved. This is shown by the curves of the flexible book at *e*, in the book rack, in Fig. 35. The book is pressed from the side, and is thus flexed or curved. Similar curves

are found in the great rock volume, caused by great pressure from forces acting horizontally, or nearly so. Fig. 40 represents an arch in the hard metamorphic rocks of the Lake Superior region.

Fig. 40.

In some cases the rocks do not bend, but are broken apart, and the pressure causes them to stand on end, or vertically. This is shown by the lower books, at *f*, in Fig. 35.

If the top of the arch, in Fig. 40, were worn off, the rocks of the sides would be vertical, or nearly so, and would have the appearance of having been broken apart at the time of their upheaval.

In Fig. 40, the rocks in the lower part of the picture stand at a high angle of inclination.

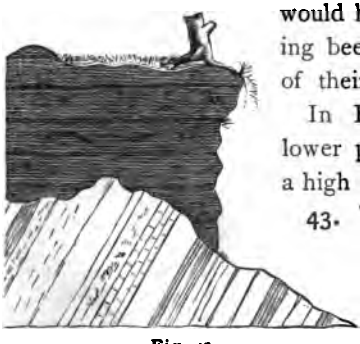


Fig. 41.

43. **Unconformable rocks.**—After rocks have been tilted, it sometimes happens that other rocks are formed upon them, and the want of harmony in their position shows that they were formed at a later period. This is represented by the two

sets of rocks in Fig. 41, and also by the books at *f* in Fig. 35. Rocks which are thus out of harmony are said to be *unconformable; i. e.*, the upper rocks do not conform to the lower.

44. **Faults.**—We occasionally find cracks in rocks, accompanied with displacement of strata. In Fig. 42 we readily perceive that the strata are out of place. The layers *b* and *c* were evidently at one time on the same level, and formed one stratum. The line *aa* represents a great crack, and either the strata on one side were thrust up by what is termed an *up-throw*, or those on the other side were depressed by what is called a *down-throw*. Such displacements are *faults*. If *b* were a seam of coal, the miners in following up the seam would lose it at the crack *aa*, and would be at fault until they had found it again at *c*.

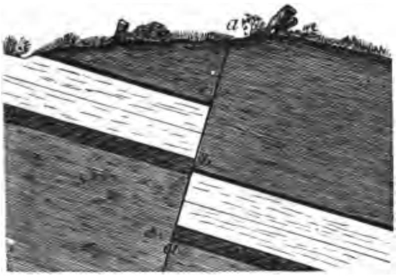


Fig. 42.

CHAPTER V.

Historical Geology.

45. Progressive History.—The earth has had a progressive geological history. This history may be read in two ways. By one method, we begin with the more recent time, and trace the record back to the more ancient. The knowledge of a later age throws light upon the preceding one. This order was adopted by the late Sir Charles Lyell, the distinguished English geologist. The other method is to begin with the oldest rocks, and trace the history down to the present time. This method has been adopted by Prof. Dana, and by most American geologists. It has the advantage of beginning with the first chapter of the great stone book, and of reading the story in the order in which it was written. We shall adopt the latter method.

46. Relative ages of rocks—how determined.—How may we know that one rock-formation is older than another? If the rocks are little disturbed, that is, have not been displaced, we know that the top rock is more recent than the one underneath. In a wall of masonry, the lowest course of stones is laid down first, and the other courses follow

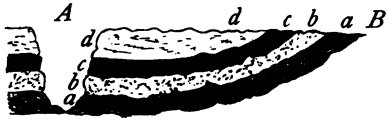


Fig. 43.

in regular order, from the bottom to the top. So each

rock-formation was laid down by the waters upon an older one. If in a ravine or valley, *A*, Fig. 43, you should find the rocks in the order *a*, *b*, *c*, and *d*, you would say that *a* is the oldest, *b* next, and so on. Having carefully studied these rocks, so as to be able to identify them, you would recognize them in traveling from *A* to *B*, and would know that *b* is not so old a rock as *a*.

But if you were in the ravine *A*, Fig. 44, you would be wrong in thinking that the rock *f* is next in age to *a*, for in some deeper ravine to the right or left of *A* you would find that *b*, *c*, *d*, and *e* were formed before *f*. Here is a case of unconformability.

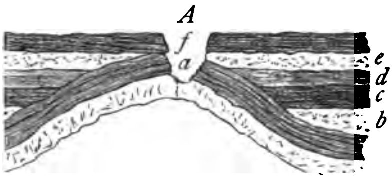


Fig. 44.

Sometimes the strata are so *folded* by lateral pressure as to bring the older rocks above the younger. The subsequent erosion of the top of the folds leaves the rocks as shown along the horizontal line *AB*, in Fig. 45.

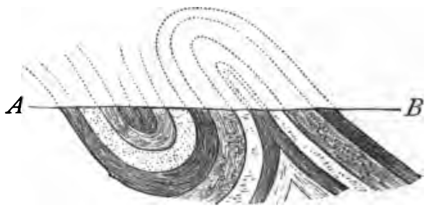


Fig. 45.

A *fault* may also cause the older to be thrown above the younger. This is shown in Fig. 46, where the fault *ab* has thrown up the stratum *a'* from its place at *a*. Suppose, after this

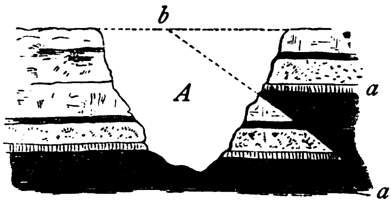


Fig. 46.

up-throw, a ravine, *A*, should be formed, then you would find on the right hand side of the ravine apparently two distinct strata, *a* and *a'*, whereas both are one, and were formed at the same time.

But suppose we find some rock quite by itself, far away from all other known rocks, can we tell its relative age? Sometimes we can, if the mineral character of the rock is such that we can identify the rock with one of ascertained age. But it is seldom safe to trust to the testimony of the rock itself, for rocks of exactly the same age change within short distances from sandstone to shale or to limestone and the like, or from a non-metamorphic to a metamorphic rock.

47. **Fossils as a guide.**—The value of organic remains, as a guide in determining the relative ages of rocks, depends upon the supposition that in the long succession of animals and plants in the past, each species lived only for a limited period. The rocks formed during that period would alone contain the remains of such species. If, for example, a certain species of shell is found in the rocks of the formation marked *C*, in Fig. 47, and has not been found

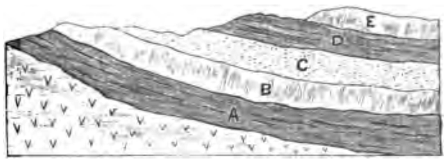


Fig. 47.

in *B* below nor in *D* above, the inference is, that if we find the same species elsewhere, the formation containing it will be in age the equivalent of *C*. But should it afterwards be found in any rocks higher or lower than *C*, its value is lost with reference to *C*. It is safer to take all the forms found in *C* as a guide, for it is quite unlikely that the whole group of fossils in *C* will be found in any other formation, above or below. By studying carefully all the fossils in the several formations, from *A* to *E*, it is

ascertained that each formation has an assemblage of fossils peculiar to itself. *A* and *B* might have some forms of fossils common to both, and perhaps *A* and *C*, although in less number, but it would be unexpected if we found any forms common to *A* and *E*. Unfortunately, we do not certainly know when any species of animal or plant first began its existence, nor do we know how long it may have continued. We merely know where we have found it. A species of shell may, in a given locality, have run its race, and died out completely, because, it may be, the waters were too muddy or too sandy, while at some other locality, where the conditions of living were more favorable, it may continue to exist for a long time, and contribute to the fossils of a later formation. A little shell, called *Lingula*, now living in the sea, is found among the fossil shells of the oldest fossiliferous rocks. The modern species differ from the ancient, but they are of the same type, and look very much alike. These are shown in Figs. 88 and 89.

Fig 48.

Apiocystis Gebhardi.

Prof. Dana states that, "catastrophes may affect the borders of an ocean or shallow seas that do not reach the greater depths. Fossils of the group called *Cystids* (Fig. 48) occur only in the older rocks of the globe, and were supposed to have become extinct at the time of their disappearance as fossils; but recently they have been found in the depths of the Atlantic Ocean, a region not reached by the agencies of extermination that swept, from time to time, over the continental seas. It was formerly supposed that no species that is now alive existed anterior to the Tertiary;

but in the same deep ocean, one living mollusk has been found that is supposed to date back to the Cretaceous or Chalk Era."

Notwithstanding the difficulty of using fossils as a means of determining the relative ages of rock-formations, there can be no doubt of their value for this purpose, when carefully and wisely used. The more fully fossils are collected and studied, the less the uncertainty in our conclusions.

48. Classification of Rocks. — Following the general plan accepted by Prof. Dana, the grander divisions of Geological History are called TIMES, as the ARCHÆAN TIME. Times are divided into AGES, as the AGE OF FISHES, or the DEVONIAN AGE. Ages are divided into PERIODS, as the LOWER CARBONIFEROUS PERIOD of the Carboniferous Age. Periods are divided into EPOCHS, as the BURLINGTON EPOCH of the Lower Carboniferous Period.

49. Archæan Rocks.—The oldest known rocks are called the ARCHÆAN, from a Greek word meaning *beginning;* and the division in time in which these rocks were formed is called the ARCHÆAN TIME. It is subdivided into two Periods: the LAURENTIAN, from the river St. Lawrence, on which rocks of this period are found; and the HURONIAN, named from Lake Huron, for the same reason.

(1) The LAURENTIAN is the older period. Its rocks are chiefly granite, gneiss, syenite, and extensive beds of crystalline limestone. These were all originally sedimentary rocks, formed of the waste of preëxisting rocks; but the preëxisting rocks have never been discovered. There was, of course, a first surface rock, the original crust-rock of the earth, but it has been largely worn away to form later rocks, and the eroded areas are now buried.

The rocks of the Laurentian Period have been much disturbed, and they are every-where tilted and broken.

(2) HURONIAN PERIOD. — Overlying the Laurentian, but unconformably, are the Huronian rocks, composed of slates, conglomerates, quartzites, thin beds of limestone, etc. The *Copper-bearing* rocks of Lake Superior rest conformably upon the Huronian, and some geologists regard them as a part of the Archæan series. Others regard them as belonging to the Silurian Age, which follows the Archæan. The Archæan rocks were formerly believed to be entirely destitute of fossils, and were consequently called *Azoic*, from two Greek words meaning *without life*, but a coral-like fossil, called *Eozoon*, or dawn-animal, as showing the dawn of animal life, has been found. This will be described hereafter.

50. **Palæozoic Time.** — The Palæozoic Time follows the Archæan. Palæozoic means *ancient life*, and in this Time living forms became abundant.

The Palæozoic Time is divided into three well-marked Ages: the SILURIAN, DEVONIAN, and CARBONIFEROUS.

51. **The Silurian Age** is the oldest. It derives its name from the Silures, a tribe of ancient Britons which lived in Wales and in an adjoining portion of England, a region in which the Silurian rocks were first studied and named by the late Sir Roderick Murchison, an eminent English geologist.

In North America, the Silurian rocks are divided into LOWER and UPPER.

(1) The LOWER SILURIAN rocks are again divided into three Periods, viz., the PRIMORDIAL (meaning *first in order*), which includes the *Acadian* and *Potsdam* Epochs; the CANADIAN Period, including the *Calciferous* (*lime-bearing*), *Quebec*, and *Chazy* Epochs; and the TRENTON Period, which is made up of the *Trenton*, *Utica*, and *Cincinnati* Epochs. Several of these names, viz., Potsdam, Chazy, Trenton, and Utica

are names of localities in New York, where the rocks they designate are found.

(2) The UPPER SILURIAN rocks belong to four Periods, viz., the NIAGARA, including *Medina*, *Clinton*, and *Niagara* Epochs; the SALINA, in which the *Onondaga Salt* Group of New York was formed; the LOWER HELDERBERG; and the ORISKANY. These are all New York names.

The rocks of the different Periods of the Silurian Age are generally to be found in the Interior States, as will be seen hereafter.

Few, if any, remains of fishes or other animals having vertebræ, or back-bones, have been found in the Silurian rocks of North America, and for this reason the Silurian Age is sometimes called the Age of Invertebrates.

52. **The Devonian Age.**—This Age succeeds the Silurian, and derives its name from Devonshire, England, where the rocks of this Age were early studied.

The Devonian Age is divided into four Periods, viz., CORNIFEROUS, HAMILTON, CHEMUNG, and CATSKILL. The last three names are those of localities in New York.

(1) The term CORNIFEROUS is derived from two Latin words, *cornu* (*horn*) and *fero* (*I bear*), *i. e.*, hornstone-bearing, signifying the flint or hornstone abounding in the Corniferous limestones. In New York the Corniferous is divided into three Epochs, viz., *Cauda-galli* (named from a fossil sea-plant, the leaves of which have a whorl resembling the tail of a rooster), the *Schoharie*, and the *Corniferous* proper. The rocks of the first two of these divisions have not been recognized in the Interior States, but the Corniferous limestone is found in several States. The State House at Columbus, Ohio, is built of it.

(2) The HAMILTON PERIOD is divided into *Marcellus*, *Hamilton*, and *Genesee* Epochs.

(3) The CHEMUNG PERIOD includes the *Portage* and *Chemung* Epochs.

(4) The CATSKILL PERIOD is represented by heavy sandstones in the Catskill Mountains, N. Y. No Catskill rocks have been found further west than West Virginia.

Fig. 49.

53. In the foregoing outline of the Formations, it has been noticed that a large number of the names are New York names. The geological map of New York, Fig. 49, shows the locations of the principal points. The Adirondack Mountains are in the Archæan rocks, while north and south are Lower Silurian rocks. In these are to be seen Potsdam, Chazy, Trenton, Utica, and the Hudson River;

the latter giving name to rocks which in the Interior are now generally called the Cincinnati Group.

In the Upper Silurian, on the map, are seen Niagara, Medina, Clinton, Salina (where is the Onondaga Salt Group), and Oriskany. The Lower Helderberg, in the Helderberg Mountains, could not be well shown in the Upper Silurian area on the map.

In the Devonian area, which covers nearly all of the south half of the State, are found Schoharie, the Helderberg Mountains, in which are found the Upper Helderberg Group (corresponding to the Corniferous), Marcellus, Hamilton, Genesee, Portage, and Chemung.

As the older rocks were first carefully studied in New York, it was to be expected that the local names of that State should be applied to them. If the investigations had begun in the Interior, where these rocks are generally better developed, the names of the formations would have been Western names.

54. **The Carboniferous Age.**—Next above the Devonian, we have the Carboniferous Age, which is divided into three Periods. These are the LOWER CARBONIFEROUS, the COAL-MEASURES, and the PERMIAN.

The term Carboniferous means *carbon-producing.* Coal is largely made up of carbon, and the Age is the Coal-producing Age. During this Age the great coal formations of the United States and Europe were deposited.

(1) The LOWER CARBONIFEROUS rocks, sometimes called the Sub-carboniferous, are well developed in the Interior States. They are divided into the following Epochs or Groups: *Waverly*, *Burlington*, *Keokuk*, *St. Louis*, and *Chester.*

The oldest of these, the Waverly, derives its name from a place of that name in Ohio, where the rocks are quarried. It includes the *Chouteau* rocks of Missouri; the *Kinderhook*

beds of Illinois and Iowa; the *Marshall* Group of Michigan; and the *Knobstone* rocks of Kentucky and Indiana. The *Chester* Group takes its name from a locality in Illinois, where the rocks are found. The other groups are named from cities on the Mississippi River.

(2) The COAL-MEASURES constitute the middle Period of the Carboniferous Age. During this Period all the coal-fields of the Interior States were formed. In some of these States the strata are divided into *Lower* and *Upper* Coal-measures, but such divisions are rather for convenience than because there is any geological reason for them.

Sometimes the lowest of the rocks of the Coal-measures is a *Conglomerate* sand-rock. This is also called the *Mill-stone Grit*, a term borrowed from English geology. The Conglomerate is often wanting in the coal-fields of the Interior States, and the term has for us comparatively little geological significance.

(3) The PERMIAN PERIOD.—The rocks of this Period rest upon the Coal-measures. The term Permian comes from Permia, an ancient kingdom in Russia, where the rocks of this Age were first investigated by Murchison and others. A few Permian fossils are found in Kansas and Nebraska, mingled with those of the Coal-measures, and some geologists call the rocks containing them *Permian*. Others call them *Permio-carboniferous*. No valuable seams of coal are found in them. With the Permian, the series of the rocks of Palæozoic Time ends.

55. **Mesozoic Time**, or the Time of Middle Life.—This is sometimes called the Reptilian Age, because some of the most remarkable and characteristic animal forms imbedded in the rocks are reptiles. The Mesozoic Time is divided into three Periods: the TRIASSIC, the JURASSIC, and the CRETACEOUS. No Triassic and Jurassic rocks are found

in the Interior States. The name Triassic comes from the triple division of the rocks of this Period in Europe. Jurassic is derived from the Jura Mountains in Switzerland. Cretaceous comes from *creta*, the Latin word for *chalk*. The principal chalk formations of the world belong to the Cretaceous Period. Cretaceous rocks are found in north-western Iowa and in south-western Minnesota. There are beds of true chalk in Kansas.

56. **Cenozoic or Recent Time.**—This is the latest of the great divisions of geological history. It is divided into two leading Ages—the TERTIARY and QUATERNARY AGES. The terms *Primary* and *Secondary*, formerly used to denote the earlier rocks, are now abandoned.

The Tertiary is sometimes called the Mammalian Age, from the abundance of mammals found in the rocks.

(1) The TERTIARY AGE is divided into three PERIODS: the EOCENE, or dawn of recent time, MIOCENE, and PLIOCENE—the latter terms meaning degrees of recentness. Rocks of the Tertiary are found in the Interior States—in south-western Kentucky, south-eastern Missouri, and in southern Illinois.

(2) The QUATERNARY AGE is the most recent of all, and comes down to man's appearance upon the Earth. It begins with the DRIFT PERIOD—named from the bowlders, gravel, sand, etc., brought or drifted from regions to the northward, and spread over the surface. This is followed by the CHAMPLAIN PERIOD, which derives its name from the terraces on the banks of Lake Champlain. After the Champlain follows the RECENT PERIOD, which brings us within the limits of historical times, in which man plays a part.

57. The Formations included in Historical Geology, beginning at the surface, are shown in the table on page 64. A more detailed Chart of the Formations of the Interior States may be found on pages 62 and 63.

CHART OF FORMATIONS

			Illinois.	Missouri.	Iowa.	Indiana.
CENOZOIC TIME.			Drift. Tertiary.	Drift. Tertiary.	Drift. ?	Drift.
MESOZOIC TIME.				L. Cretaceous.	Inoceramus. Woodbury. Nishnabot'ny.	
PALÆOZOIC TIME.	Carboniferous Age. Age of Plants.	Permian.	Permian ?	Permian ?		
		Coal-meas.	Coal-meas.	Coal-meas.	Coal-meas.	Coal-meas.
		Lower Carboniferous.	Chester. St. Louis. Keokuk. Burlington. Waverly. [*Kinderhook*]	Chester. St. Louis. Keokuk. Burlington. Waverly. [*Chouteau*]	St. Louis. Keokuk. Burlington. Waverly. [*Kinderhook*]	Chester. St. Louis. Keokuk. Waverly. [*Knobstone*]
	Devon. Age. Age of Fishes.		Black Shale. Hamilton. Corniferous.	Black Shale ? Hamilton. Corniferous.	Hamilton.	Black Shale. Hamilton. Corniferous.
	Silurian Age. Age of Invertebrates.	Upper Silurian.	Oriskany. L. Helderb'g. Niagara.	Oriskany. L Helderb'g. Niagara.	Niagara.	Oriskany. L. Helderb'g. Niagara. Clinton.
		Lower Silurian.	Cincinnati. Galena. Trenton. St. Peter's S.S. L. Mag. L. S.	Cincinnati Galena. Trenton. Black River. Birdseye. 1st Mag. L. S. 1st Sandstone. 2d Mag. L. S. 2d Sandstone. 3d Mag. L. S. 3d Sandstone. 4th Mag. L.S. Potsdam S. S.	Cincinnati. [*Maquoketa*] Galena. Trenton. St. Peter's S.S. L. Mag. L. S. Potsdam S. S.	Cincinnati.
ARCHÆAN TIME.				Huronian. Laurentian ?	Sioux Quartzite.	

IN THE INTERIOR STATES.

Kentucky.	W. Virginia.	Ohio.	Michigan.	Wisconsin.	Minnesota.
Tertiary.		Drift.	Drift.	Drift.	Drift.
					Lower Cretaceous.
Coal-meas.	Coal-meas.	Coal-meas.	Coal-meas.		
Chester. St. Louis. Waverly. [*Knobstone*]	Chester. Umbral. Vespertine.	Chester. Waverly.	Carb'f's L.S. Mich. Salt G. Waverly. [*Marshall G.*]		
Black Shale. Hamilton. Corniferous.	Catskill. Chemung. Portage. Hamilton.	Erie Shale. Black Shale. Hamilton. Corniferous.	Black Shale. Chemung. Portage. Hamilton.	Hamilton.	
? Niagara. Clinton.	Oriskany. L. Helderb'g. Niagara ? Clinton.	Oriskany. L. Helderb'g. [*Water Lime*] Onondaga. Niagara. Clinton.	L. Helderb'g. Salina. Onondaga. Niagara. Clinton.	L. Helderb'g. Niagara. Clinton.	Niagara.
Cincinnati.	Cincinnati. Trenton.	Cincinnati.	Cincinnati. Trenton. Chazy L. S. Calcifer. S. S. Potsdam S. S. [*St. Marys*] Cop. Rocks.	Cincinnati. Galena. Trenton. St. Peter's SS. L. Mag. L. S. Potsdam S.S. Cop. Rocks.	Cincinnati. [*Maquoketa*] Galena. Trenton. St. Peter's SS. L. Mag. L. S. Potsdam S. S.
			Huronian. Laurentian.	Huronian. Laurentian.	Archæan.

ORDER OF ROCKS.

CENOZOIC TIME.	Quaternary, or Age of Man.		Surface Soil, etc.	Interior States.
			Champlain Period.	
			Drift Period.	
	Tertiary, or Mammalian Age.		Pliocene Period.	
			Miocene Period.	
			Eocene Period.	Interior States.
MESOZOIC TIME.	Reptilian Age.		Cretaceous Period.	
			Jurassic Period.	
			Triassic Period.	
PALÆOZOIC TIME.	Carbonif. Age, or Age of Coal Plants.		Permian Period.	Interior States.
			Coal-measures.	
			Lower Carboniferous Period.	
	Devonian Age, or Age of Fishes.		Catskill Period.	
			Chemung Period.	
			Hamilton Period.	
			Corniferous Period.	
	Silurian Age, or Age of Invertebrates.	Upper.	Oriskany Period.	
			Lower Helderberg Period.	
			Salina Period.	
			Niagara Period.	
		Lower.	Trenton Period.	
			Canadian Period.	
			Primordial, or Cambrian Period.	
ARCHÆAN TIME.			Huronian Period.	
			Laurentian Period.	

CHAPTER VI.

GEOGRAPHICAL GEOLOGY.

58. Method of Study.—It is not difficult to learn the Geography of Geology, or where the different formations are to be found, if we are guided by some simple plan of study. In common geography, if we would remember the locations of states, we keep in mind their relations to something else; as, for example, to the Atlantic or Pacific coasts, to the Mississippi River, or to the Great Lakes. In this way the states are tied together in groups. If we can do something like this in the Geology of the Interior, our work will be easy.

There are four coal-fields in the Interior, the locations of which may be remembered as readily as if they were four lakes. The most northern of these is the MICHIGAN coal-field, in the Lower Peninsula of Michigan. In shape this field is almost a circle.

The most eastern is the great ALLEGHANY coal-field, which extends from northern Pennsylvania to the southwest, through eastern Ohio, West Virginia, eastern Kentucky, and eastern Tennessee into Alabama.

The third, or great MIDDLE coal-field, is situated in Illinois, western Indiana, and western Kentucky.

The fourth, or great WESTERN coal-field, is found

in Iowa and Missouri, extending westward into Nebraska and Kansas, and southward into the Indian Territory and Arkansas.

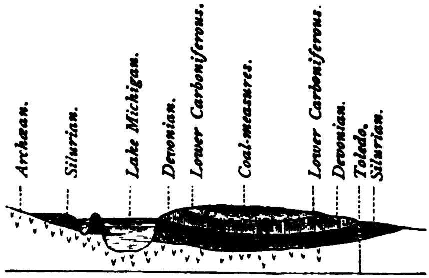
59. **These four coal fields** represent the highest rocks in the Interior States, excepting some small areas of Cretaceous in north-western and western Iowa and in Minnesota, and of Tertiary in south-western Kentucky and south-eastern Missouri. If, therefore, we travel in any direction from these coal areas, we descend in the geological series. It is like stepping down stone steps, the top step representing always the coal rocks. This may be illustrated by Fig. 50. The top step represents the COAL-MEASURES; the next, the LOWER CARBONIFEROUS; the third, the DEVONIAN; the bottom one, the SILURIAN; while the ground may be called the ARCHÆAN, which is the foundation of all. By keeping in mind the simple idea of steps, and of the order in which they lie, we are prepared to explore the Interior States, and gather the materials for a geological map. We shall make what are called *geological sections*, which are simply the records of the rocks found, arranged in the form of diagrams.

Fig. 50.

60. **First Journey.** — Let us first start from the center of the Michigan coal-field and go to the north-west into the Upper Peninsula. If we mark the Coal-measures black, as in Fig. 51, we have made a beginning of our section. Going north-west, we find rocks of the Lower Carbonifer-

ous, which we indicate on the section by the dotted band. Farther on we come to Devonian rocks, which we mark by vertical bars or dashes. Next we find some Silurian rocks in the Upper Peninsula, to be marked by horizontal dashes or shading. Beyond these are Archæan rocks, bordering Lake Superior in the region of Marquette. We represent them by angles upon a white surface.

Fig. 51.



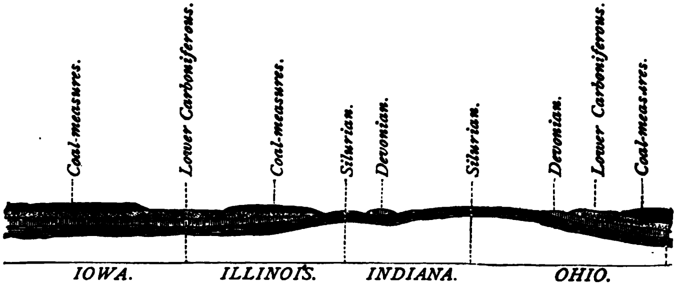
If, from our first starting place, we go to the south-east, to Toledo, in Ohio, we pass from the Coal-measures down to the Lower Carboniferous, thence down upon the Devonian, and from the latter upon the Silurian, the upper beds of which are found at Toledo. We have thus made a geological section, and also learned that the rocks lie much after the manner of stone steps, but steps with their upper corners worn off.

61. Second Journey.—This will be a longer one. Let us start from the Alleghany coal-field, in north-eastern Ohio, and go westward across the northern edge of the Middle coal-field in Illinois to the Western coal-field in Iowa. The rocks passed over are given in Fig. 52.

Beginning in the East, we pass down from the Ohio coal-field over the Lower Carboniferous and Devonian to the Silurian. In Indiana we ascend to the Devonian, to descend again upon the Silurian, and travel upon the latter into Illinois. Here let us pause and take breath, for the next step upward will be, geologically, a long one. We

must climb from the Silurian to the Coal-measures, the Lower Carboniferous and the Devonian being gone. Here the top stone rests upon the fourth in the regular series.

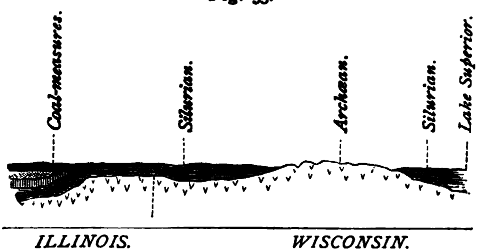
Fig. 52.



Passing westward from the Illinois coal-field, we descend upon the Lower Carboniferous (here in its proper place), and, after entering Iowa, ascend upon the rocks of the Western coal-field. The section, Fig. 52, shows all this, and how much of the journey was made in each of the several States.

62. Third Journey. — Having found two steps missing in Illinois in our last excursion, let us make a new section from the Middle coal-field in Illinois, northward through Wisconsin to Lake Superior. This section is shown in Fig. 53.

Fig. 53.

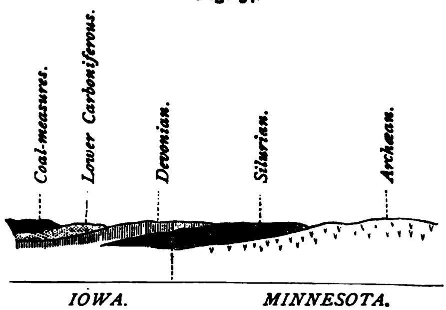


Here the Coal-measures rest directly upon the Silurian, as we had discovered in the last journey. We follow the Silurian north some distance, into Wisconsin, and then find

the old Archæan rocks, which we cross. On the northern flank of these rocks, we find a belt of Silurian extending along the shore of the Lake. The larger part of this journey is performed in Wisconsin.

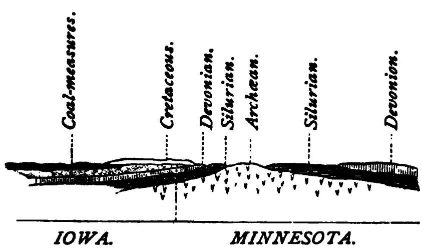
63. **Fourth Journey.**—If we make another excursion from the Western coal-field, starting from Des Moines, Iowa, and go northward through St. Paul, Minnesota, we make a regular descent from the Coal-measures to the old Archæan, passing over the Lower Carboniferous, the Devonian, and the Silurian. This route is shown in the geological section recorded in Fig. 54. In this section it will be seen that the steps—the Lower Carboniferous and the Devonian—which were missing in northern Illinois, are found in their proper places in northern Iowa.

Fig. 54.



64. **Fifth Journey.**—If, however, we change our last route, and go from the Coal-measures of Iowa to the northwestern part of Minnesota, we shall find a somewhat different section. Our first step is upward upon rocks of Cretaceous age, rocks much more recent than the Coal-measures. From

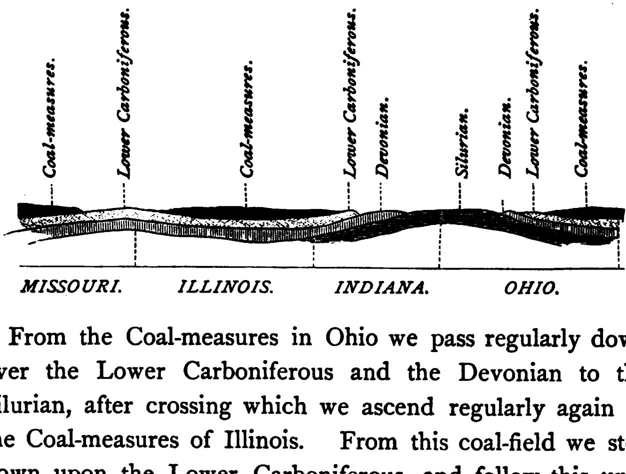
Fig. 55.



these we pass down to the Devonian, here a narrow belt; thence to the Silurian, also a narrow belt. Beyond the Silurian, we find the Archæan, which extends to the south-west from the region of Lake Superior. From these Archæan rocks we rise again upon the Silurian, and then again upon the Devonian, found in the valley of the Red River of the North. This section is shown in Fig. 55, on the preceding page.

65. Sixth Journey.—Leaving the more northern portion of the Interior States, let us start again from the Alleghany coal-field in Ohio, and travel westward, passing a little north of the center of the Middle coal-field in Illinois, and thence to the Western coal-field in Missouri. This journey is shown in the section in Fig. 56.

Fig. 56.



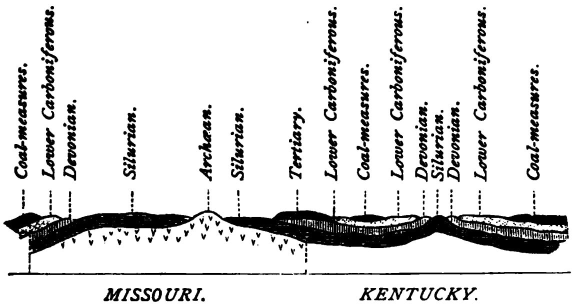
From the Coal-measures in Ohio we pass regularly down over the Lower Carboniferous and the Devonian to the Silurian, after crossing which we ascend regularly again to the Coal-measures of Illinois. From this coal-field we step down upon the Lower Carboniferous, and follow this until we ascend to the Coal-measures of Missouri.

66. Seventh Journey.—If from our last starting point in Ohio we journey eastwardly, or a little south-eastwardly,

we shall cross the Alleghany coal-field and descend to the Lower Carboniferous rocks, which form a belt around the eastern side of that field. Within this belt is the limited coal-field near Cumberland, a small part of which is in West Virginia, and the rest in Maryland. East of this belt are belts of Devonian and Silurian rocks. These belts are shown on the geological map, Fig. 59.

67. **Eighth Journey.**—Let us take one more journey, to see what we may find in the southern portion of the Interior States, especially in Kentucky and Missouri. Placing ourselves in south-western Missouri, let us travel eastward. We start upon the coal of the Western coal-field and pass down over the Lower Carboniferous and Devonian to the Silurian, on which we travel almost across Missouri. We find, however, in our course, some uplifted masses of ancient Archæan rocks, which contain the rich iron ores of

Fig. 57.



Iron and Shepherd mountains, and of Pilot Knob. Following our course, we touch upon the northern edge of some Tertiary deposits, bordering the Mississippi River both in Missouri and Kentucky, and extending south in widening area, covering large portions of the Gulf States. In Missouri they lie upon the Silurian, and in Kentucky upon the

Devonian and Lower Carboniferous. Our route touches the southern point of the Middle coal-field. From this field we pass down over the Lower Carboniferous and the Devonian to a narrow point of Silurian, which extends northward from Tennessee into southern Kentucky. From this lower formation we ascend regularly the various steps to the Coal-measures of the Alleghany coal-field, in south-eastern Kentucky. This journey is shown Fig. 57.

68. Method of mapping the Sections.—It is by the aid of a large number of geological sections, such as have been given, that a good geological map of the Interior States can be made. The sections are placed in outline upon an ordinary map, and then connected. Let us see how this may be done. Suppose we have made three sections on lines nearly parallel, as, for example, *AB*, *CD*, and *EF*, shown in Fig. 58. Beginning on the left, we mark, by the small letters *a*, *b*, *c*, and *d*, the limits of the Coal-measures, the Lower Carboniferous, the Devonian, the Silurian, and the place of the Archæan. By connecting the letters *a*,*a*,*a*, by a line, we have pretty nearly the limit of the coal-field in that direction. In the same way, by connecting the other letters by lines, we obtain the limits of the other formations. We have thus made a map. Such a map can be made very accurate by making many sections, and by following the general lines *aaa*, *bbb*, etc., and noting all the irregularities in the outcrops of the different formations.

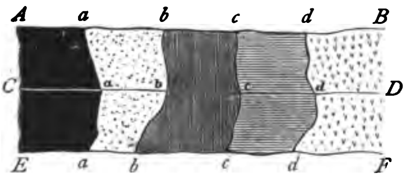


Fig. 58.

We are now prepared to understand the large map of the Interior States, Fig. 59. The symbols denoting the

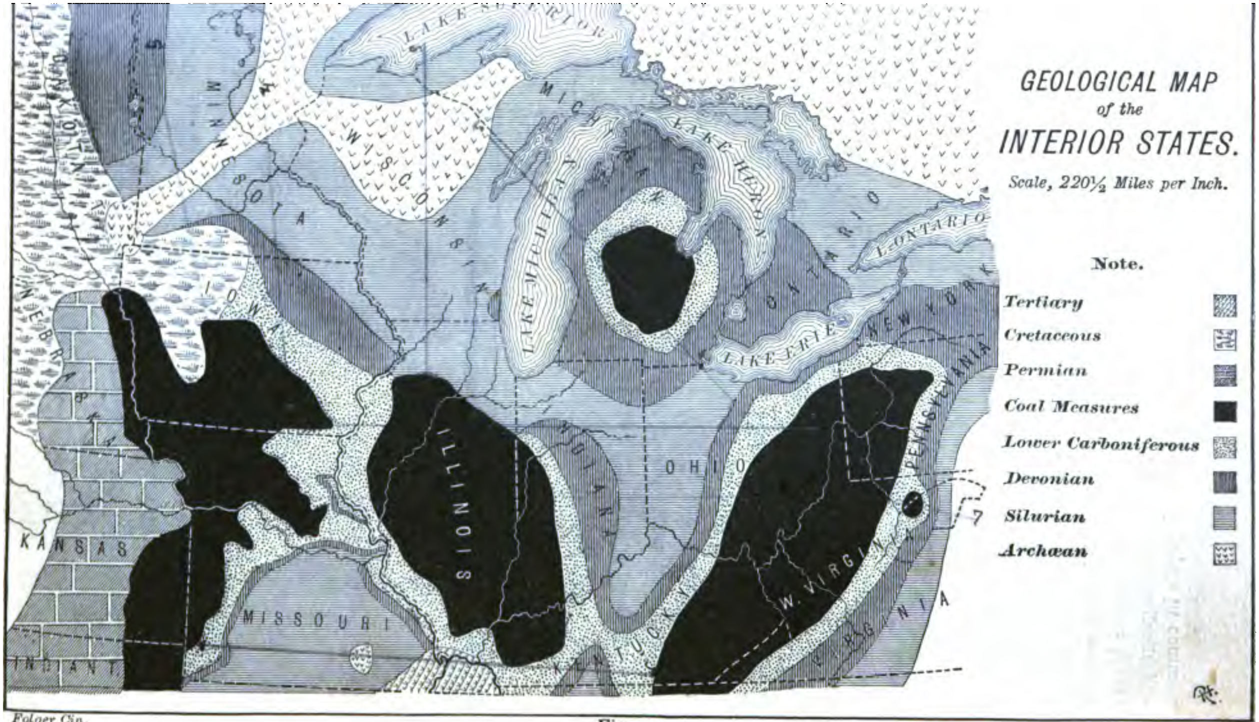
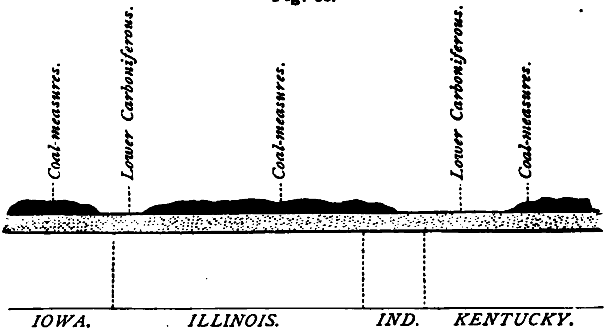

GEOLOGICAL MAP
of the
INTERIOR STATES.
Scale, 220½ Miles per Inch.
Note.
Tertiary
Cretaceous
Permian
Coal Measures
Lower Carboniferous
Devonian
Silurian
Archæan
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
L. ONTARIO
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
ONTARIO
NEW YORK
PENNSYLVANIA
W. VIRGINIA
VIRGINIA
KENTUCKY
MISSOURI
KANSAS
NEBRASKA
DAKOTA
Folger Cin.

Fig. 59.

different rocks are the same as those used in the sections in this chapter; *i. e.*, black for the Coal-measures, dotted areas for the Lower Carboniferous, etc., etc. The scale of distances is also the same as in the sections.

Fig. 60.



69. Study of the Map.*—This map should be carefully studied. Let the student first fix in his mind the positions of the four coal-fields, for these furnish the simple key to the whole map. He will next find that these coal-fields, in the Interior States, are every-where bordered by Lower Carboniferous rocks. The exceptions to this rule are in the Silurian rocks which border the Middle coal-field on its northern side, in Illinois; and in the Cretaceous rocks which overlie the north-western portion of the great Western coal-

* NOTE.—It is very desirable that the pupil should obtain mastery of the geological map. A little practice in making sections will greatly assist in fixing in his mind the geographical location of the different formations. Sections can be taken from the map, and enlarged on the blackboard. When possible, let the teacher obtain the geological map of the State in which his school is, and require his pupils to study it carefully and be able to draw it on the blackboard. In this way the same definiteness of knowledge in geographical geology will be obtained that is expected of pupils in common geography.

field, in Iowa. By a careful inspection of the map he will see that, in Kentucky, where the Alleghany and Middle coal-fields are nearest together, the Lower Carboniferous stretches entirely across the interval, and the same is true in the narrow space between the Middle and Western coal-fields, in Illinois and Iowa. This is shown in the section, Fig. 60.

It is the opinion of some geologists that these coal-fields were once united, and that from these intervals the coal rocks have been since removed.

From the Lower Carboniferous we pass down to the Devonian rocks, which form skirting belts of varying widths, and these, in turn, rest upon the Silurian. In upper Michigan, Wisconsin, and Minnesota, the Silurian rocks are bordered by those of the old Archæan Age, the lowest of the geological series. In Missouri the Silurian encloses small areas of Archæan rocks, as at Iron Mountain and Pilot Knob, which were doubtless islands in the ancient Silurian ocean.

70. **Cretaceous rocks** are seen on the map in north-western Iowa and south-western Minnesota. They rest upon the Coal-measures and upon all the lower formations down to the Archæan. This is shown

Fig. 61.

in the Section, Fig. 61. It will be noticed that the Cretaceous rocks are not conformable with those below. They were not deposited until long after the time of the Coal-measures.

71. **Tertiary rocks.**—In the vicinity of the mouth of the Ohio River, and below, on both sides of the Mississippi River, are deposits of Tertiary Age. These are represented on the map by symbols explained in the margin.

72. **Permian rocks.**—In Kansas and Nebraska, rocks are indicated on the map on the west side of the Western

coal-field, which are marked Permian. They contain some Permian fossils, and are regarded by some geologists as true Permian rocks. Others regard them as merely belonging to the Upper Carboniferous. They may perhaps be considered as beds of passage or transition from the true Coal-measures to the true Permian. They contain no available seams of coal, but coal may be reached by sinking shafts down through them to the underlying Coal-measures.

Recently bones of saurians of Permian types have been found at the summit of the Coal-measures in Illinois, and Prof. Cope regards them as proof of a true Permian Period.

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CHAPTER VII.

CLASSIFICATION OF ANIMALS AND PLANTS.

As the remains of animals and plants are imbedded in the rocks, and enter largely into the science of Geology, it is necessary to give a brief outline of the leading divisions of the Animal and Plant kingdoms.

73. **The Animal Kingdom** may be divided into five great classes, or sub-kingdoms, viz., VERTEBRATES, ARTICULATES, RADIATES, MOLLUSKS, and PROTOZOANS.

I. VERTEBRATES are animals possessing a *vertebral column*, or backbone. This column is made up of separate bones, called *vertebræ*. To this kingdom belong man, quadrupeds, birds, reptiles, and fishes.

(1) *Mammals*, the highest of the vertebrates, are animals which suckle their young, as horses, dogs, and other quadrupeds, and also whales, which are air-breathing, warm-blooded animals. Mammals give birth to their young.

(2) *Birds* are warm-blooded, and hatch their young from eggs.

(3) *Reptiles* are hatched from eggs, but are cold-blooded air-breathers. They include alligators, lizards, snakes, and turtles. Frogs and salamanders are reptiles, and, when young, breathe by gills like fishes, but afterwards by lungs.

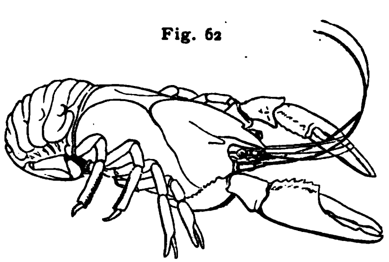
(4) *Fishes* are cold-blooded, and are produced from eggs, and breathe by gills. Many of the old fossil fishes were

covered with hard scales, like the gar-pike of the Interior waters. They are called Ganoids because of their hard, shining scales.

It will be seen, in subsequent chapters, that animal remains, representing all these divisions, are found in the rocks. The remains of Man, however, are in quite recent deposits. Fishes are believed to have made their appearance on the earth before any of the other vertebrates.

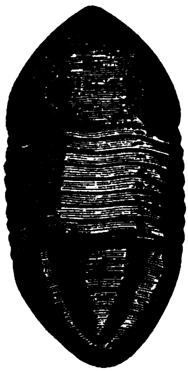
II. ARTICULATES. — Animals of this sub-kingdom are jointed, or articulated (Latin, *articulatus*). To this class belong craw-fishes, lobsters, spiders, insects, worms, etc. Fig. 62 is a common craw-fish, found in the streams and wet lands of the Interior. Trilobites, so frequent in the old fossiliferous rocks, are articulates of the order of Crustaceans, which includes lobsters, crabs, etc. Fig. 63 represents the crust or shell of an old trilobite, found in the limestone rocks near Cincinnati. Spiders and other insects have been found in the rocks, and also traces of worms.

Fig. 62



Craw-fish.

Fig. 63.



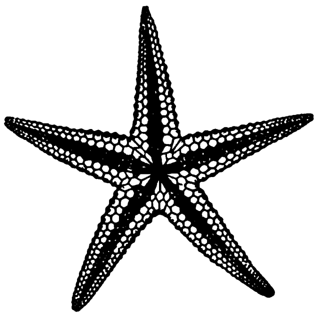
Trilobite.

III. RADIATES. — In animals of this sub-kingdom, the parts radiate from a common center. This is seen in the star-fish, a fossil form of which is shown in Fig. 64.

To the Radiates belong the sea-urchins, so very abundant along our shores, and also found in the rocks. They are

covered with spines, and, when these are removed, the surface is covered with radiating dots and tubercles.

Fig. 64.



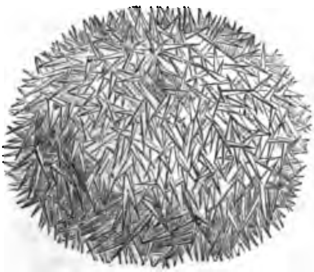
Star-fish.

A modern sea-urchin is shown in Fig. 65, as it appears with spines.

Fig. 66 shows the surface with the spines removed.*

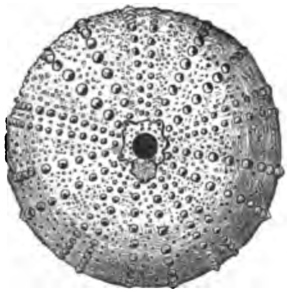
Crinoids, which are found in the rocks of the Interior in great variety, and which are thought to be the most beautiful of all our fossils, are Radiates. There are living species, one of which is shown in Fig. 67. The Polyps, which form most of the corals, are Radiates.

Fig. 65.



With Spines.

Fig. 66.



Without Spines.

Sea-urchin.

IV. Mollusks are shell-fish, such as snails, mussels, oysters, clams, etc., which abound on the land and in fresh and salt waters. The land-snails in some countries are quite large. The larger part of Mollusks appropriate lime,

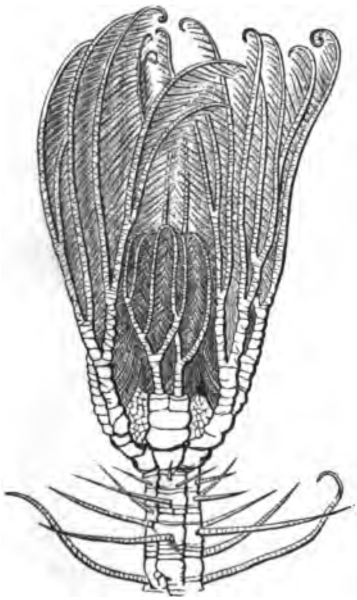
* These figures are from Tenney.

which forms the shells or hard parts. The shell not being easily destroyed, is preserved in the rocks.

Following Dana, there are three grand divisions of Mollusks, viz., Ordinary Mollusks, Ascidian Mollusks, and Brachiate Mollusks.

1. *Ordinary Mollusks*, such as oysters, snails, etc., are subdivided into:

Fig. 67.



A Living Crinoid.

(1) Acephals, or headless mollusks, as the clam;

(2) Cephalates, having a head, like the snail; and

(3) Cephalopods, with arms encircling the head, as the cuttle-fish and nautilus.

2. *Ascidian Mollusks* have a leathery or membranous exterior, the name being derived from the Greek word ἀσκὸς, meaning *a leathern wine bottle.* They are soft and perishable, and are not preserved in the rocks.

3. *Brachiate Mollusks* have no regular branchiæ, or gills. Their shells are bivalve, but arranged so that the opening and hinge lines are horizontal instead of vertical.

The Brachiopods, so abundant in the rocks of the Interior in the forms of Lingula, Orthis, Productus, etc., belong to the Brachiate division.

V. PROTOZOANS.—These animals are generally very small, and extremely simple in structure. They take from the

waters silica or lime, and from these materials form shells of great beauty. The leading kinds of Protozoans are the Rhizopods (Foraminifers) and Sponges.

1. *Rhizopods.*—Illustrations of Rhizopods are seen on page 40. These tiny animals are so numerous that they contribute largely to the ocean bed; and, in earlier times, have helped to form strata of considerable thickness.

2. *Sponges.*—Many have supposed the Sponges to be plants, but recent investigations show them to be animals. These animals unite in millions to form a gelatinous mass (*sarcode*), in which is secreted a skeleton. The common sponges are such skeletons, of a horny texture, but set with minute needles or spicules of silicious or calcareous matter. The glass sponges are much more beautiful, and present the appearance of most delicate lace work, spun from films of glass. One of these is shown in Fig. 68.

Fig. 68.

Euplectella cucumer.
(Reduced.)

The animals which form these wonderful sponges are the very lowest in the scale. "These creatures perform all the essential functions of life without a single organ. The mass of animal jelly takes in food without a mouth, digests it without a stomach, and rejects such portions as it can not assimilate without an alimentary canal. It inhales the sea water, extracts from it the life-sustaining oxygen, and exhales it loaded with carbonic acid—the product of animal combustion—without lungs, blood vessels, or pectoral muscles."

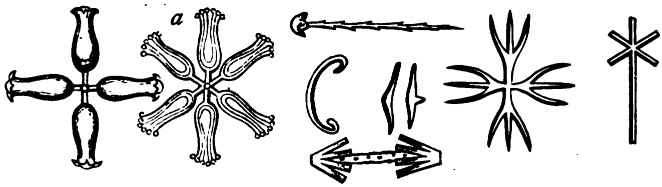


Fig. 69.

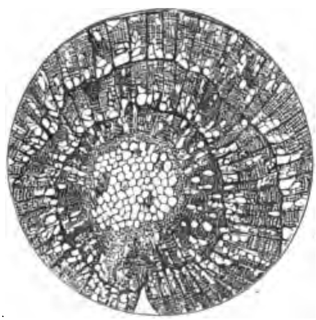
Fig. 69 represents some of the spicules which are found in the glass sponges. They are all very minute. The one marked *a* is but one three-hundredth of an inch in diameter.

74. **Plant Kingdom.** — Plants are divided into two great branches — FLOWERLESS (Cryptogams), and FLOWERING (Phænogams).

I. THE FLOWERLESS, or Cryptogamous plants, do not bear distinct flowers, nor produce proper fruit; but they have spores which serve the purpose of a true seed. The fern is a plant of this class, and on the under side of the leaf are thousands of minute spores enclosed in capsules.

The Cryptogams are divided into several groups.

Fig. 70.



Oak Wood.

(1) *Acrogens*, which include ferns, lycopods (ground or trailing pines), and the equiseta or horse tails (scouring rushes). The trees and plants of the Coal-measures were chiefly acrogens, as will be seen hereafter.

(2) *Anogens*, including the mosses and liverworts.

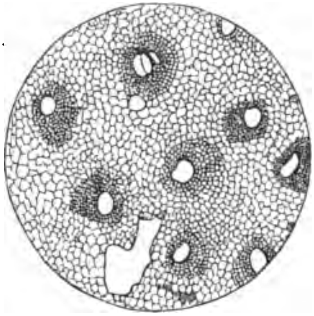
(3) *Thallogens*, including the sea-weeds (Algæ), lichens, growing on rocks, trees, old rails, etc., and fungi — toadstools, puff-balls, etc., etc.

II. The Flowering (Phænogamous) plants bear true flowers and true seeds. They may be divided into three classes:

(1) *Gymnosperms*, those having naked seeds, as the pines, cedars, larches, etc., and also the Cycads of the Tropics.

(2) *Angiosperms*, those having covered seeds. This class includes our most common trees—the apple tree, elm, ash, sycamore, etc.

Fig. 71.



Sugar Cane.

It is a peculiarity of this class, and of the one last mentioned, that they are outside growers; that is, they make each year a ring of growth, on the outside of the trunk, under the bark. The rings harden into wood, and may be counted to ascertain the age of the tree.

These rings of growth are shown in Fig. 70, which represents a transverse section of oak wood.

The usual term to denote this outside growing is exogen, and such trees are called *exogens*.

(3) The third class of plants is the opposite of the others—they are inside growers, or *endogens*. They grow from within, like a corn-stalk. This class includes palms, bamboos, canes, grains, grasses, etc. By referring to Fig. 71, a magnified cross-section of a sugar cane, it will be seen that the structure of the inside growers is quite unlike that of the other.

Representatives of nearly every leading kind of plant have been found in a fossilized state. Traces of Algæ are found in the oldest rocks. Acrogens furnished matter for the more ancient coal-beds, and Endogens and Conifers for the more modern. Conifers lived in the Devonian Age.

The earliest known land plants were Acrogens in the Lower Silurian Age. It is supposed that the conditions of plant-life were more uniform in earlier than in later times, and that the different continents in ancient times had relatively more species in common than now.

The classification of plants may be shown in a table as follows:

PLANT KINGDOM.	Flowerless Plants, or Cryptogams.		Acrogens.	Ferns. Lycopods. Equiseta.
			Anogens.	Mosses. Liverworts.
			Thallogens.	Algæ. Lichens. Fungi.
	Flowering Plants, or Phænogams.	Exogens.	Gymnosperms.	Conifers. Cycads.
			Angiosperms.	Ordinary Trees. Shrubs.
			Endogens.	Palms. Canes. Grasses, etc.

77. 79R.

CHAPTER VIII.

ARCHÆAN TIME.

75. WE shall now notice the rocks of the Interior States somewhat in detail, and we begin with the oldest—those of the ARCHÆAN TIME.

The accompanying outline map, Fig. 72, shows the Archæan lands of North America. Doubtless, hereafter, it will be found that portions of the lands now regarded as Archæan are of a later age, the rocks having been so changed by metamorphic agencies as to resemble those of the older formations.

In the Interior States, Archæan rocks are found in the upper peninsula of Michigan, in Wisconsin, Minnesota, Iowa, and Missouri. In Canada the rocks of this Time have a very wide range, as shown on the map.

The Archæan Time is divided into two Periods—the *Laurentian* and the *Huronian*.

76. **Archæan Rocks of Michigan.**—In the Upper Peninsula, the Laurentian rocks cover a total area of 1839 square miles. This is made up of several smaller areas, one of which touches Lake Superior a little above Marquette, while the others lie a few miles south of the Lake. The Laurentian rocks are chiefly granite, gneiss, syenite, and crystalline limestone. Thus far they have afforded no useful minerals.

Fig. 72.

77. **Fossil remains.**—The Archæan rocks were formerly regarded as containing no traces of life, and hence were commonly called the *azoic* rocks; *i. e.*, rocks without life. But within a few years, a coral-like fossil has been discovered in the Laurentian rocks of Canada, which Dr. Dawson calls the *Eozoön Canadense*, or Canadian dawn-animal, because it denotes the dawn of animal life.

Fig. 73.

Fig. 73 represents the fossil, highly magnified. It should be stated, however, that some

have denied animal origin to the Eozoön, and attribute the form to mineral crystallization.

Graphite, the mineral of which lead pencils are made, is found abundantly in the Laurentian rocks of Canada. It is composed chiefly of carbon, which, it is believed, came from plants. Hence it is inferred that vegetation, probably marine, existed in the early Laurentian Period.

The Huronian rocks of Michigan cover a district of quite irregular outline, containing 1992 square miles. This district touches Lake Superior at Marquette and at the head of Keweenaw Bay. The rocks are chiefly slates, conglomerates, quartzites, and thin beds of limestone. They are much broken and tilted, and lie unconformably upon the Laurentian rocks. No fossils have been found in them.

78. **Huronian Iron Ores.**—The Huronian formation in Michigan contains vast beds of iron ore. The ores are the magnetic, specular hematite (often called the red specular), and soft hematite, resembling the brown hematite of other states. The magnetic and specular ores are the most prized. About fifty mines are now wrought. In 1856 only 7000 tons of ore were mined, while in 1877 there were 1,018,520 tons. A little of this ore is smelted in charcoal furnaces in the Upper Peninsula, but the larger part is shipped to states south of the Lakes, chiefly Pennsylvania, Ohio, and Indiana, where it meets the coal from the coal-fields.

79. **The ores are of sedimentary origin,** and are regularly interstratified with the other rocks of the Huronian series. They were once mud, largely charged with iron, but have been changed and hardened by heat and pressure. They have been much disturbed and broken, and lie at all angles of inclination. In the following map, Fig. 74, we have the ore as shown at Republic Mountain in Marquette

County, Michigan. Here the rocks form a curious basin, of which one end and parts of two sides are seen, reminding one of a pile of baking dishes set in each other. If all the dishes of the pile were hard-baked stone-ware, excepting one, which was an *iron pan*, we should have a good idea of this famous ore deposit. The inner and more darkly shaded band, *aa*, represents the ore, which extends almost around Smith Bay, an enlargement of the Michigamme River. The ore belt, with an average width of 350 to 400 feet, has been traced for more than two miles. The inner half of the belt, marked by the dark shading, is composed of very rich specular and magnetic ore, while the outer portion is a ferruginous flint, or jasper. This vast body of ore doubtless curves under the Bay, as shown in the cross section, Fig. 75. It will,

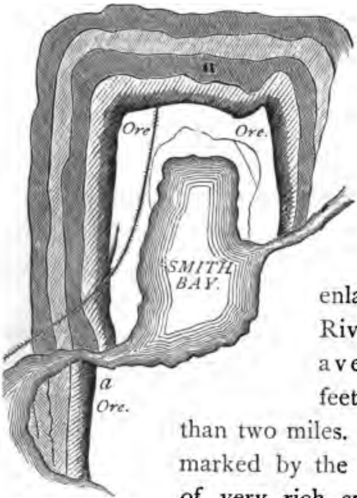


Fig. 74.

however, be a long time before the ore under the Bay will be needed, for there is a ridge of ore most of the way around the Bay, from 100 to 180 feet above the water—an immense body above drainage—which may be mined most advantageously. Analyses of the ore gave, for the specular, 67.21 per cent of iron

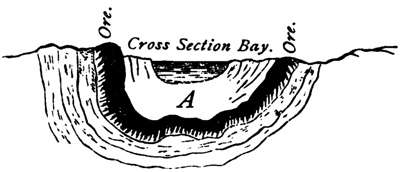


Fig. 75.

and only 0.03 per cent of phosphorus; and for the magnetic, 65.81 per cent of iron and 0.06 per cent of phosphorus.

There are, besides, other important mines on Michigamme Lake and River, all of which are now reached by railroads.

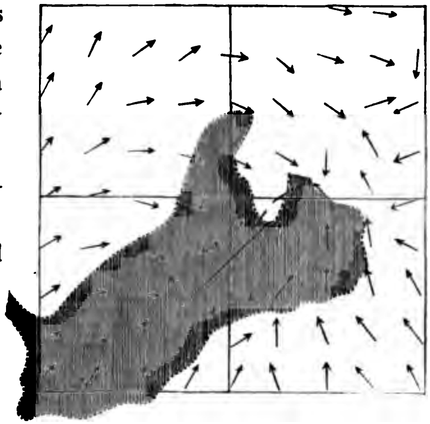


Fig. 76.

In 1850, the Government geologists, Messrs. Foster and Whitney, in a Report to the Hon. Thomas Ewing, Secretary of the Interior, state that "this lake (Michigamme) is seldom visited by the white men, but the Indians resort here to hunt and trap. Along its shores are valuable deposits of iron, and its solitudes may be disturbed in the present century by the sound of the forge-hammer and the puff of the steam-engine." Scarcely more than twenty years had passed away before this prediction was fulfilled.

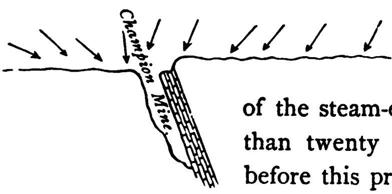


Fig. 77.

80. Magnetism.—The effect of the magnetic ores on the magnetic needle is very great, and the needle is often used in searching for them. The accompanying diagram, Fig. 76, represents the variations of the needle in a space 200 feet square. Ore has been dug in the shaded space. Fig. 77 shows the dip of the needle in the vicinity of the Champion Mine.

81. Analyses of Ores.—The following table from the Michigan Geological Report shows the average richness of the iron ores from the leading mines of the Lake Superior region:

1. Red Specular ore.
2. Black Magnetic and Slate ore.
3. Soft Hematite ore.
4. Flag ore.

	1.	2.	3.	4.
Per cent of metallic iron	62.91	62.93	52.65	49.33
" " phosphorus	0.11	0.085	0.078	0.053
" " sulphur	0.05	0.013	0.11	0.03

The phosphorus is given because, if in the ore, it enters the iron, making it brittle, or "cold-short," when cold; while the effect of the sulphur in the iron is to make it brittle, or "red-short," when hot.

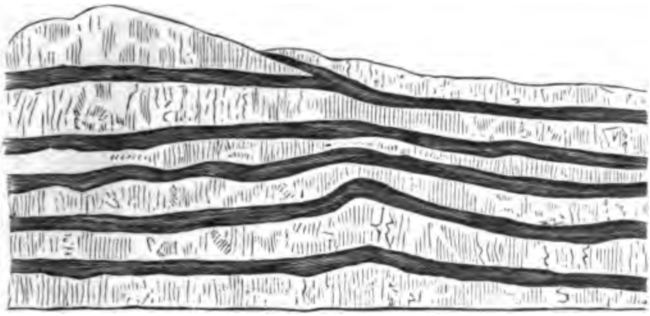
82. The Copper-bearing Rocks of Lake Superior rest conformably upon the Huronian, and are thought by some to belong to the Huronian Period rather than to the Silurian, which follows it. Others, however, include the Copper Rocks in the early Silurian series.

The large quantity of metallic, or "native," copper found in these rocks gives them great interest, and makes them more remarkable than the famous iron ore series just described. The Lake Superior region is the chief locality of the world yielding native copper.

The copper-bearing rocks extend eastward along the south shore of the Lake for more than forty miles, and then, forming a narrow belt, stretch in a north-east direction for about a hundred miles to the extremity of Keweenaw Point—a tongue of high land which reaches almost to the middle of the Lake.

83. Chief Source of the Copper.—The copper is found in a peculiar rock, called melaphyre. It is commonly considered an igneous, or trap, rock, but Prof. Pumpelly, of the Michigan Geological Survey, states that "it is still an open question whether the trap which formed the parent rock of the melaphyre was an eruptive or purely a metamorphic rock." In the one case it was thrown up in a melted state, and in the other it was deposited as a sedimentary rock. The melaphyre is associated with beds of conglomerate, and appears to be interstratified with them. Sometimes bands of slate separate the beds of melaphyre, as shown in Fig. 78.

a
b
a
b
a
b
a
b
a
b
a



a Trap beds.
b Slate beds.

Fig 78.

The native copper is sometimes in massive sheets, sometimes in mere strings, and again in globules. Native silver, in grains and threads, is often associated with the copper. Copper is also found on Isle Royale. Near the north shore of the Lake is a very small island, called "Silver Islet," scarcely above the water, upon which is a valuable silver mine. Col. Whittlesey reports silver ore in connection with a black slate of the Potsdam series. This slate is seen on Little Iron River, on the south shore of the Lake.

84. Ancient Copper Mines. — In the copper region, both on the main land and on Isle Royale, many ancient mining pits have been discovered, from which very con-

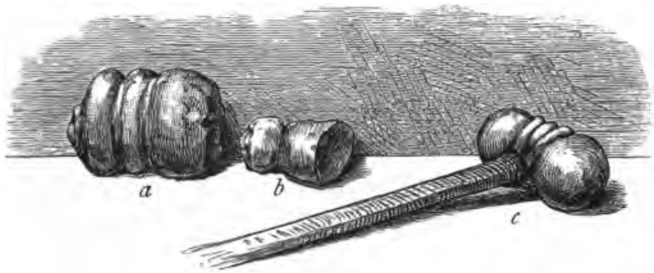


Fig. 79.

siderable quantities of copper must have been taken. These ancient excavations extend for many miles along the lines of the veins. These pits are believed to have been dug by the people who built the old mounds so frequently seen in the Interior States. In these mounds copper implements and ornaments are often found. Large numbers of stone

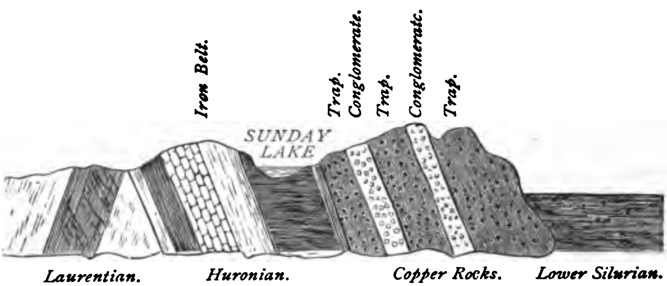


Fig. 80.

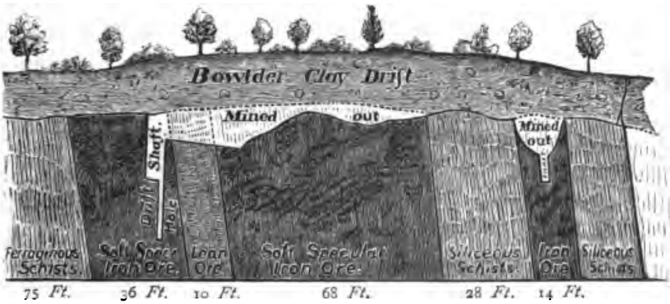
hammers remain in the pits, made from hard bowlders picked up on the shore of the Lake. In Fig. 79, *a* and *b*, we have pictures of two of these stone mauls; *c* shows a

method of applying a handle. Ten cart-loads of old hammers were found at one location.

85. A geological section, partly ideal, of the rocks between Lake Gogebic and Montreal River (given in the Geological Report) presents the relations of the Laurentian, Huronian, Copper-bearing, and Silurian rocks. This section is given in Fig. 80.

It should be repeated that many of the geologists who have explored the Lake Superior region regard the Conglomerates of the Copper series as Silurian, and not of an earlier date.

Fig. 81.

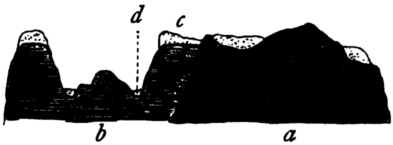


Commonwealth Mine, Wisconsin.

86. Archæan rocks in Wisconsin. — The Archæan rocks of Michigan extend in a south-westerly direction into Wisconsin, but are generally covered by thick masses of drift, sand, and gravel. The drift-covered hills are reported to be 1100 or 1200 feet above the level of Lake Superior. The Huronian portion of the Archæan, which includes the Penokee range, is said to be 4,000 feet in thickness. In Oconto County, Wisconsin, extensive beds of iron ore have been found, one of which, the Commonwealth Mine, is shown in Fig. 81. There are 118 feet of excellent ore in the three seams, and the location is one of great promise.

87. The copper-bearing series, in Wisconsin, composed of trap, conglomerate, and sandstone, is enormously thick. In Ashland County there are 10,000 feet of upturned sandstones, and Prof. Irving estimates the thickness of the whole series "at apparently four miles, and, in some places, much more than this." Very little copper has been found as yet. Fig. 82 represents one of several bold hills of Archæan quartzite, found in Sauk County, Wisconsin. The strata dip at a high angle, while the Potsdam sandstones, which rest upon the flanks of the older rocks, are horizontal. The Archæan rocks evidently formed islands in the old Potsdam sea.

Fig. 82.

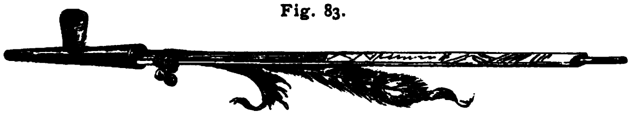


a Archæan. *c* Conglomerate.
b Potsdam. *d* Drift.

88. Archæan rocks in Minnesota.—The area occupied by the Archæan rocks in this State is large. It extends across the northern border, and, forming an elbow in the north-east, sweeps in a belt diagonally through the State to the south-west corner. It is called the "granite and metamorphic region." This region has not as yet been so fully studied as to make it possible to give the outlines of the Laurentian and Huronian areas. Probably some of the metamorphic rocks will prove to be of Silurian age.

Near the south-western corner of the State is a hard, reddish, metamorphic sandstone, called the *Sioux quartzite.*

Fig. 83.



An Indian Pipe of Peace.

Interstratified with the quartzite, at one point, is a thin layer (one foot thick) of red indurated clay, or pipe stone (Catlinite), which has been used very largely by the Indian tribes for the manufacture of pipes. The stone is soft enough to be easily carved, yet hard enough to take something of a polish. The quarry, which has been a famous one with the Red Men, and from which "pipes of peace" and other pipes used on noted occasions were made, is situated about thirty miles north of the south-west corner of the State, and about four miles east of the west line.

89. **Archæan rocks in Iowa.**—The red or Sioux quartzite, referred to in the last paragraph, extends from Minnesota into the north-western corner of Iowa. Prof. C. A. White regards this rock as of Archæan age.

Bowlders of this quartzite—some rounded and some angular—are scattered over the prairies of western and central Iowa, and over north-western Missouri.

Resting unconformably upon the quartzite are beds of Cretaceous rocks. The relations of the two may be seen in Fig. 84.

Fig. 84.

Sioux Quartzite. Archæan. *Section in North-western Iowa.* Cretaceous.

90. **Archæan rocks in Missouri.**—In the iron ore district about Iron Mountain and Pilot Knob, the porphyry rocks associated with the ores are regarded as belonging to the Archæan Time, and as the equivalents of the Huronian or iron-bearing rocks of Michigan. Overlying the porphyries are limestones of the Silurian Age. To the east are granites older than the porphyries.

91. Iron ores of the Iron Mountain region.—The most famous localities of ore are Iron Mountain, Pilot Knob, and Shepherd Mountain.

(1) *Iron Mountain* is a flattened conical hill, 228 feet high, and covers with its base an area of 500 acres. This hill is made up of stratified porphyry, in which are fissures, many of them very large, filled with specular iron ore. The gradual waste of the porphyry, from long weath-

Fig. 85.

ering, left the more indestructible ore upon the surface, and the quantity of this ore was so great as, at first, to lead to the belief that the whole hill was made of ore. Later investigations have shown that the ore is in veins, intersecting the porphyry. Fig. 85 shows one of the large veins of ore, as exposed in mining. It is a great arch, 45 feet high, the two sides, or legs, being from 12 to 18 feet thick.

(2) *Pilot Knob*, six miles south of Iron Mountain, is a bold hill, 581 feet high, with a base covering 360 acres. Here the iron ore is found in a regular stratum, or band, 40 feet thick, and not in veins as in the Iron Mountain. Fig. 86 shows the position of the ore.

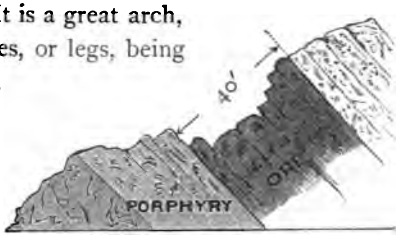


Fig. 86.

(3) *Shepherd Mountain*, near Pilot Knob, is 660 feet high. Here the ore exists in veins, in a manner similar to the formation at Iron Mountain. Some of these veins are from 10 to 20 feet wide.

92. **Quality of the ores.**—The ores of all this region are very rich in iron, and the deposits are of immense value. The vein ores of Iron and Shepherd mountains yield about 66 per cent of metallic iron, and the stratified ore of Pilot Knob about 60 per cent. The Shepherd Mountain ore is reported to be remarkably pure, containing no sulphur, and only 0.015 per cent of phosphorus. All the ores are classed as specular, although many of them are magnetic, those from Shepherd Mountain having this property more than the others.

The vast beds of iron ore in Michigan, Missouri, and Wisconsin are a magnificent legacy of the old Archæan Time to Man. They are the most extensive and valuable ore deposits in the United States, and rival the most famous of the Old World. Since the introduction of steel so largely in the place of iron, these ores, which are peculiarly adapted to steel making, because they contain so little phosphorus, become of the highest importance and value.

97.

CHAPTER IX.

LOWER SILURIAN.

93. **The Palæozoic Time,** which succeeds the Archæan, is divided into three Ages: SILURIAN, DEVONIAN, and CARBONIFEROUS. All of these Ages are well represented in the Interior States.

94. **Silurian Age, or the Age of Invertebrates.**—This Age is for convenience divided into *Upper* and *Lower*, the Niagara Group being generally regarded as the base of the Upper Silurian.

The rocks of the Lower Silurian will be considered first. They are divided by Prof. Dana into three Periods; viz., *Primordial*, *Canadian*, and *Trenton*. In the Interior States, the Potsdam rocks represent the Primordial; the Calciferous, or Lower Magnesian, and the St. Peter's Sandstone, the Canadian; and the Trenton, Galena, and Cincinnati groups, the Trenton.

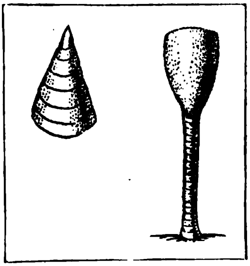
Fig. 87.

The leading divisions of the Silurian rocks, as found on the upper Mississippi River, are shown in the vertical section, Fig. 87. By the section, it

will be seen that the Potsdam sandstone is at the bottom of the series, and is therefore the oldest of the Silurian Age.

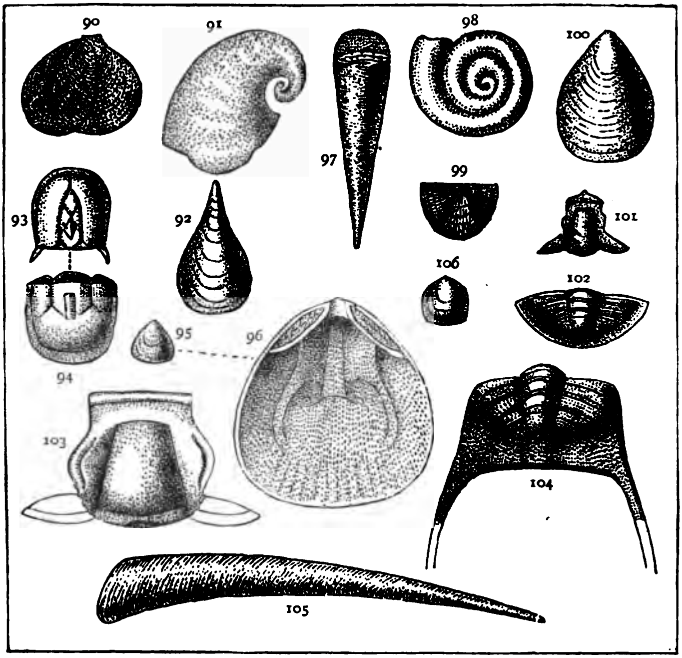
95. **Potsdam Sandstone.**—This rock takes its name from the town of Potsdam, in northern New York. It extends westward through Canada, and appears in the Upper Peninsula of Michigan, in Wisconsin, Minnesota, Iowa, and Missouri. It is generally a sand rock, and was doubtless a beach deposit along the shores of the old Archæan lands. It is reported to be 500 feet thick on the upper Mississippi. In Iowa the formation is less thick. It sometimes contains thin layers of magnesian limestone, generally fossiliferous.

96. **Fossils.**—With the exception of the Eozoön, found in the Laurentian rocks of Canada, we have in the Potsdam rocks the earliest known manifestation of life, although, doubtless, animals whose record is lost lived long before. In some places the waters abounded in mollusks and trilobites. Of the former, the *Lingula* (tongue-shaped) is one of the most interesting, from the fact that while so ancient it is also modern, for the Lingula is to be found living now. Fig. 88 represents the ancient Lingula from the Potsdam beds, and Fig. 89 a living species of the same type, growing on its foot-stalk.



Figs. 88, 89.

97. **The group** of figures (Figs. 90–106) on the following page gives many of the fossils from the Potsdam beds in Iowa, Wisconsin, and Minnesota. This is an interesting group of shells and trilobites. The trilobite, which is a crustacean, derives its name from the three lobes or ridges on its body.



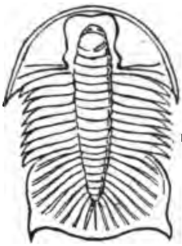
Fossils of the Potsdam Sandstone.

Figs. 90-106.

90, Lingula aurora, showing both valves; 91, Platyceras primordialis; 92, Lingulepis pinnæformis; 93, Agnostus Josepha, head; 94, Agnostus Josepha, body or pygidium; 95, Obolella polita, natural size; 96, Same, valve enlarged; 97, Theca primordialis; 98, Euomphalus vaticinus; 99, Orthis pepina; 100, Lingula ampla; 101, Conocephalites Shumardi, head; 102, Conocephalites Shumardi, body; 103, Conocephalites Ioensis, head; 104, Conocephalites, body; 105, Serpulites Murchisoni; 106, Lingula Winona.

Fig. 107 gives a restored form of another trilobite called the *Dicellocephalus Minnesotensis.* In simple English, it is the Minnesota Shovel-head. In Figs. 108 and 109 we see a Graptolite (stone writing), called *Dendrograptus Hallianus.*

It has the appearance of a plant, but it was formed by an animal allied to the polyp which forms the corals.



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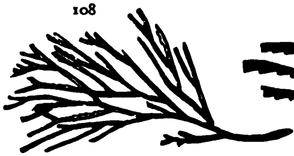


109

Figs. 107 - 109.

98. **Lower Magnesian Limestone** —Resting upon the Potsdam rocks is a formation generally called, in the North-west, the Lower Magnesian limestone; but in New York the beds of the same age are more sandy, and are known as the Calciferous (lime-bearing) sand-rock.

In north-eastern Iowa the Lower Magnesian limestone forms picturesque ledges in the hills, and adds greatly to the beauty of the landscape. Fig. 110 (from a sketch by Owen) shows a castle-like cliff of this limestone.

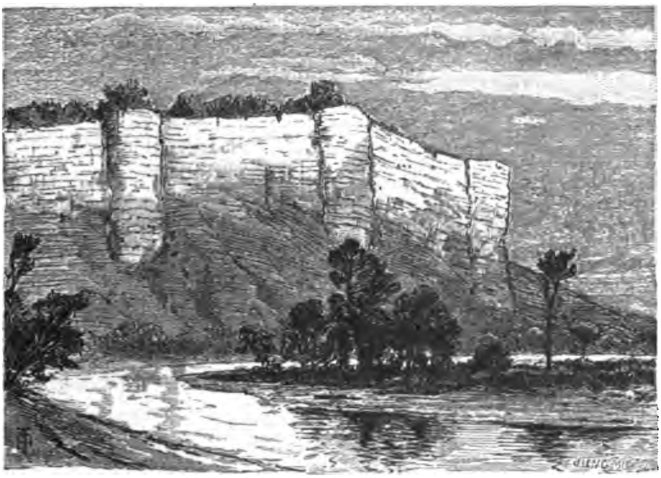
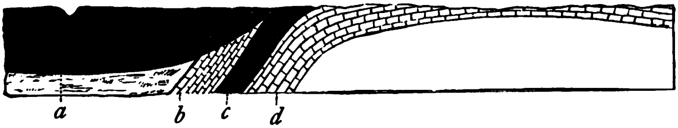


Fig. 110.

In La Salle County, Illinois, there is a remarkable uplift, by which the Lower Magnesian limestone, with the overlying St. Peter's sandstone and Trenton limestone, is

Fig. 111.



a Coal-measures. *c* St. Peter's sandstone.
b Trenton limestone. *d* Lower Magnesian limestone.

brought to the surface. This is shown in Fig. 111. The northern rim of the great Middle coal-field rests unconformably on these lower rocks.

Fig. 112.

In Ogle County, Illinois, the Lower Magnesian limestone is seen in the bed of Rock River.

In Wisconsin this limestone is reported to be 220 feet thick. Fig. 112 presents an interesting view of the junction of the Lower Magnesian limestone and the underlying Potsdam sandstone, at Lucas Point, Green Lake, Wisconsin.

99. **In Missouri**, there is an unusual alternation of limestones and sandstones, in the Lower Silurian, as seen in the section, Fig. 113. The ores of lead, zinc, copper, nickel, and cobalt, of south-eastern Missouri, are found

chiefly in the 3d Magnesian limestone of this series. This limestone is thought, by the Missouri geologists, to belong to the Potsdam Epoch, but by Dana it is assigned to the Calciferous Epoch, next succeeding the Potsdam.

The ores are found in fissures and caves in the limestone, and are sometimes disseminated in small masses in the limestone itself.

Fig. 113.

Figure 114 shows the ores at Mine La Motte, Madison County: *aa*, 3d Magnesian limestone; *b*, a layer of limestone, 10 inches thick, with some disseminated galena or lead ore; *c*, the true lead-bearing rock, containing masses of galena, accompanied, in places, with copper pyrites; *d*, a thin layer of clay slate, with ores of nickel and cobalt. This slate contains a shell of the Potsdam type, *Lingulella Lamborni; e* is a lower layer of limestone containing some lead ore.

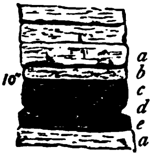


Fig. 114.

Fig. 115.


Cave, Vallè Mines, Missouri.

In the Vallè mines, lead

and zinc ores are found in caves which form a complete network under the hills. Fig. 115 represents an end view of a cave, containing ores: *aa*, limestone; *bb*, red clay, enclosing the ores; *c*, bands of zinc ore (drybone); *dd*, calamine (silicate of zinc); *e*, galena (lead ore); *f*, heavy spar (sulphate of barytes).

Fig. 116.

In some parts of Missouri the 3d Magnesian limestone forms cliffs of great beauty. Fig. 116 (after Meek) represents one of these cliffs on the Osage River.

100. St. Peter's Sandstone.—This rock takes its name from the St. Peter's River (more often called the Minnesota River), in Minnesota. It originated in a remarkable outspread of sand, often very white and pure, upon an even ocean floor. Prof. Hall states that it extends evenly, 80 feet thick, from La Salle, Illinois, for 400 miles to St. Paul, Minnesota. In some localities the rock is tinged bright red and yellow by oxides of iron. These

Fig. 117.

St. Peter's Sandstone, Kinnikinick, Wis.

colors give rise to the name pictured or painted rocks. The pictured rocks are seen in all their brightness of coloring in Allamakee County, Iowa, on the Mississippi River. In upper Michigan, the St. Peter's sandstone has not been identified with certainty. In Missouri, it is the 1st sandstone in the series given in the section, Fig. 113.

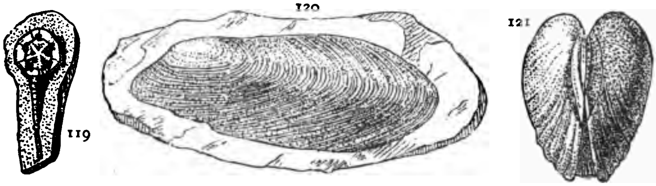
Fig. 118.

Castle Rock.

In Dakota County, Minnesota, this sandrock is seen as a remnant or outlier, and forms a marked feature in the landscape. One view of it is given in Fig. 118. The pinnacle is 70 feet above the prairie. A similar outlier of the same rock, in Wisconsin, is shown in Fig. 117. No fossils have been found in the St. Peter's sandrock.

101. **Trenton limestone.**—This formation rests upon the St. Peter's sandstone (see section, Fig. 87). It has an extensive development in the Interior States, being found in Michigan (Upper Peninsula), Wisconsin, Illinois, Minnesota, Iowa, and Missouri. It is a magnesian limestone of blue or buff color. In Iowa it attains a thickness of 100 feet. It abounds in organic remains, which represent all the great divisions of the animal kingdom, except the vertebrates. In many places the waters of the old ocean

swarmed with mollusks, trilobites, crinoids, etc. A few of the fossils are shown in Figs. 119–121, but many of these animals also lived in the time of the Cincinnati Epoch, and will be found figured with the fossils of that time.

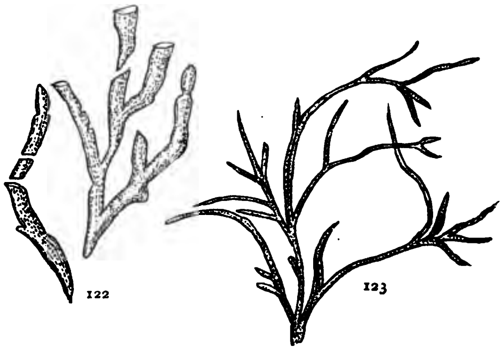


Figs. 119–121.

Fig. 119, Porocrinus pentagonus; 120, Modiolopsis orthonota; 121, Vanuxemia Dixonensis.

Doubtless marine plants were abundant in the Trenton seas of the Interior. Figs. 122 and 123 are specimens of fossil plants found in the Trenton beds in New York.

Figs. 122, 123.



Marine Plants of the Trenton Limestone.

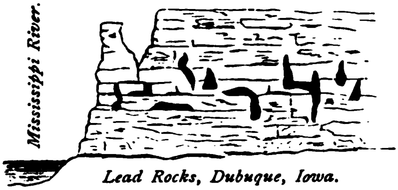
Fig. 122, Buthotrephis succulens; 123, Buthotrephis gracilis.

102. **The Galena limestone,** named from the galena, or lead ore, it contains, is regarded as the upper member of the Trenton, but from its importance it is here considered

separately. Like the lower Trenton, it is a magnesian limestone, and has a thickness of from 200 to 250 feet.

103. **The lead region** lies in north-western Illinois, south-western Wisconsin and north-eastern Iowa, near Dubuque. It has an extent of about 4,000 square miles, of which two thirds are in Wisconsin, and the remaining third nearly equally divided between Illinois and Iowa.

Fig. 124.



Lead Rocks, Dubuque, Iowa.

The galena, a combination of lead 86.6 parts and sulphur 13.4 parts, is found in crevices which are not regarded as true veins. They never extend below the bottom of the galena limestone, while true veins are of indefinite depth. In the vicinity of Dubuque, the crevices are more often found in the middle portions of the series, as shown in Fig. 124.

Fig. 125.

Marsden Lode, near Galena, Illinois.

In Fig. 125 we see a portion of a horizontal crevice, with galena in the opening, and with other ores, chiefly blende, an ore of zinc, in the roof.

Fig. 126.

Lead Mine near Dubuque.

The next figure, Fig. 126, shows a more vertical crevice. The lower part is filled with red clay, in which are scattered cubes of galena. In a narrower part of the fissure above, is a large

projecting mass of ore. Shafts or pits are sunk from the surface to reach these crevices, and sometimes very large quantities of ore are obtained.

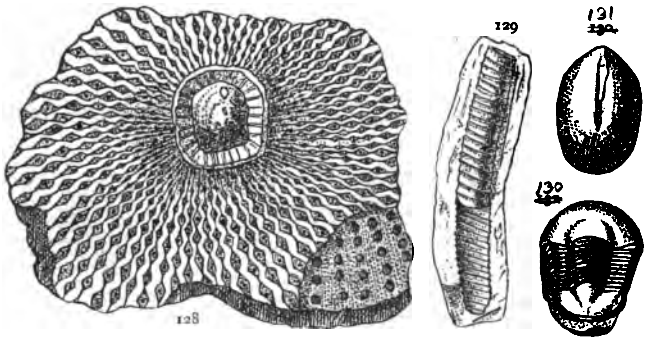
In the surface soil of the lead region, scattered blocks of ore are occasionally found. They are called "*float mineral,*" as if the ore had been drifted or floated like bowlders and dropped. They are thought to come from crevices in a higher portion of the limestone rock, now dissolved and wasted away. The ore, thus released from its imprisonment, remains in the soil where it had fallen. It should be stated that there is very little drift, *i. e.*, clay, sand, and bowlders of the Drift Period, in the lead region, and consequently the soil is composed of the disintegrated local rock.

Fig. 127.

Crystals of Galena.

104. Origin of the lead.—Prof. J. D. Whitney, who has given much attention to this lead district, thinks the ore was formed in the fissures of the limestone from an

Figs. 128-131.



Fossils of the Galena Limestone.

Fig. 128, Receptaculites Oweni; 129, Orthoceras anellum; 130, Illænus taurus; 131, Lingula quadrata.

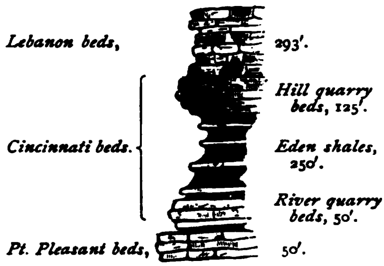
aqueous solution. The waters, which at one time filled the fissures, contained lead in solution, which, by some chemical action, was precipitated, and became attached to the sides of the rock in crystalline masses. There are also similar crystals of galena in the red clay which often fills the crevices. The galena crystallizes in cubes (see Fig. 127).

105. The Galena limestone is reported to exist in Minnesota, but little lead has yet been found in it. In Missouri, the *Receptaculites* limestone, so called from a fossil of that name, is supposed to be the equivalent of the Galena limestone, but in none of its beds have ores of lead been as yet discovered.

A few fossils from the Galena limestone are shown in Figs. 128–131. Fig. 128 is a fragment of a beautiful coral; 129 and 131 are mollusks; and 130 is a trilobite.

106. The Cincinnati Group.—This group of rocks rests upon the Trenton, the upper member of which, in the Northwest, is the Galena limestone last noticed. It was formerly called the Hudson River Group, and is still so called by some; but as the rocks are well exposed in the neighborhood of Cincinnati, and are filled with the fossils characteristic of the group, the name has been changed.

Fig. 132.



Cincinnati Group, near Cincinnati.

The group, as seen in the region about Cincinnati, has been divided by Pres. Orton into three parts, named in the ascending order, the *Point Pleasant*, *Cincinnati*, and *Lebanon* beds, as shown in Fig. 132. The Cincinnati beds are

subdivided into *River quarry* beds, *Eden shales*, and *Hill quarry* beds.

These divisions of the group are local, and do not apply to the group in New York and on the upper Mississippi.

107. **Distribution of the Cincinnati Group.**—The rocks of this period extend from Cincinnati northward in Ohio and south-eastern Indiana, and southward through many counties in Kentucky. In these States they have been brought to the surface by what is termed the Cincinnati uplift, a well-marked anticlinal, the rocks sloping on both sides of a central line or axis, as shown in

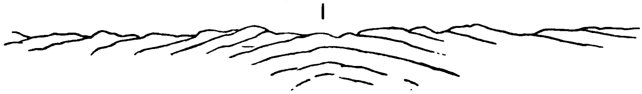


Fig. 133.

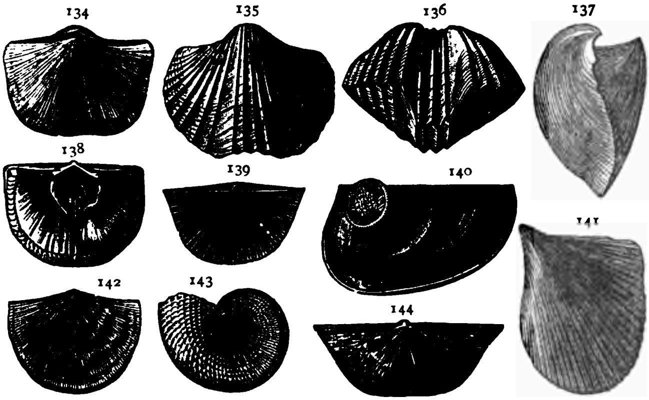
Fig. 133. According to Pres. Orton, the elevation of the Cincinnati axis above the old Silurian ocean took place at the end of the Cincinnati Period, or certainly early in the following Clinton Period. The upward movement continued, with some intervening downward movements, through the time of the deposition of the Upper Silurian and Devonian rocks—the Devonian Black Shale being involved in it.

Rocks of the age of the Cincinnati Epoch are also found in upper Michigan, Illinois, Wisconsin, Minnesota, Iowa, and Missouri. In Jefferson and Berkeley counties, in West Virginia, rocks of the Trenton and Cincinnati groups are seen.

In Iowa and Minnesota, the Maquoketa shales are referred to the Cincinnati Group; and the 100 feet of rocks in Wisconsin, lying between the Galena and Niagara limestones, doubtless belong to it. The early Ohio geologists called

the group the *Blue limestone* series. The group in the Interior States is generally composed of limestones and calcareous shales.

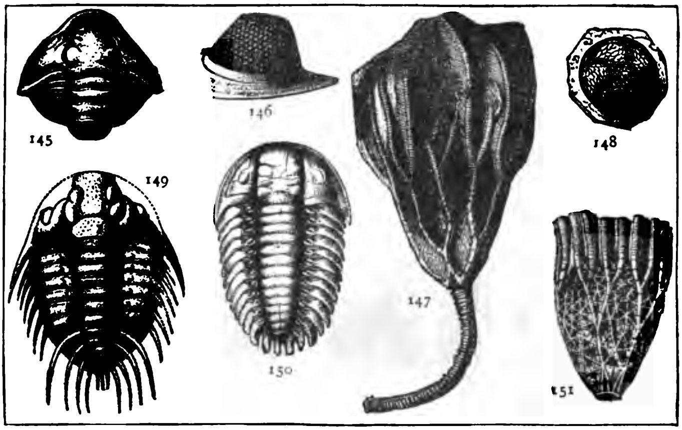
108. Fossils.—In the Cincinnati rocks, fossils are very abundant. While the variety is very considerable, the number of individuals of many species is enormous. Many large and fine collections have been made at Cincinnati.



Figs. 134-144.

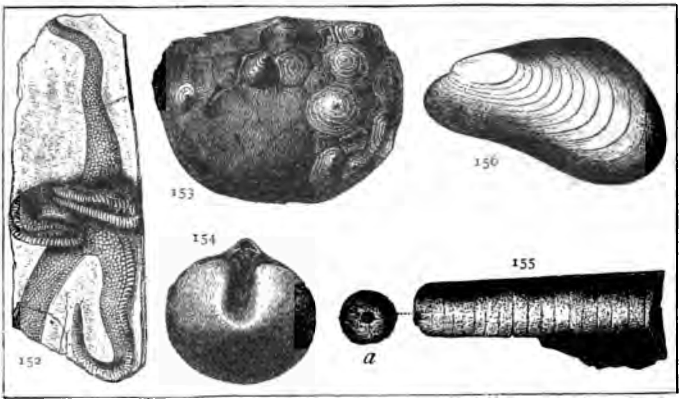
Fig. 134, Orthis occidentalis, ventral view; 135, Orthis biforata, dorsal view; 136, Same, anterior view; 137, Orthis occidentalis, side view; 138, Strophomena planumbona, inside view of ventral valve; 139, Leptæna sericea; 140, Beyrichia oculifera, magnified; 141, Ambonychia alata; 142, Strophomena planoconvexa, ventral view; 143, Cyrtolites Dyeri, magnified; 144, Leptæna sericea, inner side of dorsal valve.

Most of the above are very common in the rocks of the Cincinnati Group. The *Beyrichia* (shown in Fig. 140, considerably enlarged) is more curious, and somewhat rare. It belongs to the *Entomostraca*, one of the lower divisions of the Crustacea. All the other fossils of the above group are Mollusks.



Figs. 145-151.

Fig. 145, Calymena senaria; 146, Dalmanites Carleyi, one of the eyes magnified; 147, Glyptocrinus O'Nealli; 148, Agelocrinites Cincinnatiensis; 149, Acidaspis crosotus; 150, Ceraurus icarus; 151, Glyptocrinus decadactylus.



Figs. 152-156.

Fig. 152, Stenaster grandis; 153, Crania scabiosa, adhering to Strophomena alternata; 154, Trematis millepunctata; 155, Orthoceras lamellosum; 156, Modiolopsis modiolaris.

In the upper group, on page 112, three trilobites are given (Figs. 145, 149, and 150), and the enlarged eye of another (Fig. 146), showing the structure. Fig. 145 represents a trilobite curled up. It is often found in this way. The other fossils of this group are Crinoids, sometimes called "stone lilies."

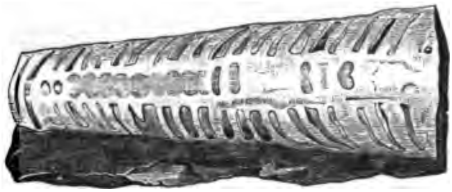


Fig. 157.

In Fig. 152 we have a Silurian Star-fish, from Richmond, Ind. Several other forms, such as *Palæaster Dyeri*, *Palæaster Jamesii*, and *Palæaster Shæfferi* have been found at Cincinnati, and named after geologists there. The little Crania (Fig. 153) is a parasitic shell, which grew upon a larger shell. Fig. 154 shows the lower or ventral side of a disc-like shell of the Brachiopoda group, from Cincinnati. Fig. 156 is a common shell, reduced in size. Figs. 155 and 157 are *Orthoceratites* (straight-horns), a straight, chambered shell, allied to the modern Nautilus.

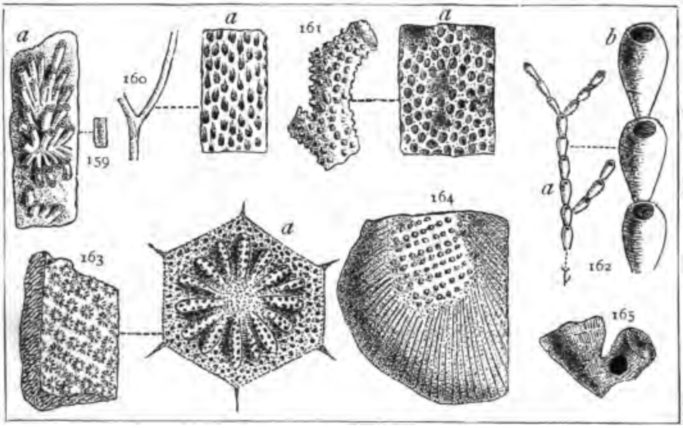
Fig. 158.

Halysites catenularius.
U. and L. Silurian.

The divisions of the outside are shown in Fig. 155, while the inside structure is seen in Fig. 157. A cavity, called a *siphuncle*, extends through the shell, generally near the center. This is seen in Fig. 157, and in Fig. 155 *a*.

Fig. 158 is a very common coral, often called the chain coral, from the chain-like appearance of the surface net-work.

All of these fossils are found in the Cincinnati Group.

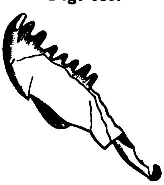


Figs. 159-165.

Fig. 159, Alecto confusa; 159*a*, enlarged; 160, Chætetes delicatulus; 160*a*, enlarged; 161, Chætetes Dalei; 161*a*, enlarged; 162, Hippothoa inflata, natural size; 162*a*, enlarged; 162*b*, three cells, still more enlarged; 163, Constellaria polystomella; 163*a*, star, magnified; 164, Chætetes Ortoni; 165, Palæophyllum divaricans, reduced.

All of the above are corals—only a few of a great variety found in the Cincinnati Group.

Fig. 166.



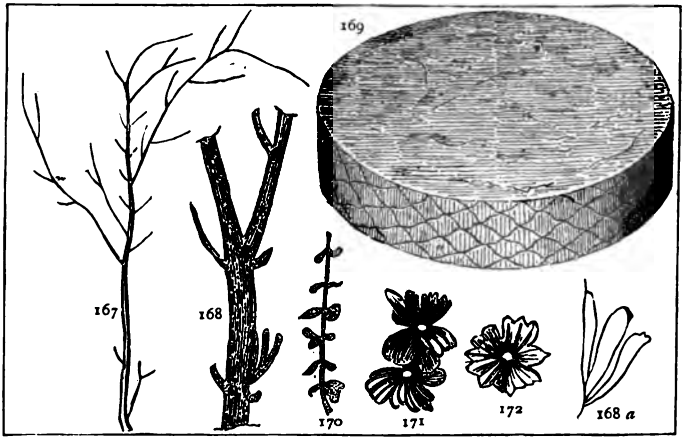
Nereidavis varians.

Prof. Wetherby, of Cincinnati, has found some minute jaws, which are supposed to be those of fossil Annelids, or worms. Fig. 166 represents one of these, highly magnified.

We have given only a very few of the vast number of the animal fossils of the Cincinnati group of rocks. The student will find them all described and figured in the Geological Reports of the Interior States, and of the State of New York. Many of the same fossils are also found in the Trenton rocks.

109. Land Plants in the Lower Silurian.—Among the most interesting and instructive discoveries is that of undoubted land plants in the Lower Silurian rocks. Some of these, recently described by Lesquereux, are given below.

Figs. 167 - 172.



Fossil Land Plants of the Lower Silurian.

Fig. 167, Psilophytum gracillimum; 168, Annularia Romingeri, enlarged; 168 *a*, Leaves of same enlarged: 169, Protostigma sigillarioides; 170, 171, 172, Sphenophyllum primevum.

Fig. 167 belongs to a genus of Lycopodiaceous plants, established by Dawson. The oldest species described by him are from the Gaspè beds of Canada, in the Upper Silurian. Fig. 167 was found by Mr. Ed. Ulrich in the banks of the Licking River, at Covington, Ky., opposite Cincinnati, in the Cincinnati Group of the Lower Silurian, and sent to Lesquereux by Rev. H. Herzer. Fig. 170 was also found at Covington, by the same person. Fig. 171 is a beautiful specimen, found by Prof. Mickleborough within the corporate limits of Cincinnati, about 375 feet

above the low water of the Ohio. Fig. 172 is a very distinct leaf, found by Mr. C. B. Dyer. Fig. 169 is a Lycopod, allied to the Lepidodendron of the Coal-measures. It was found by Dr. S. S. Scoville, in the Cincinnati Group, near Lebanon, Ohio, and is probably the first land plant ever discovered in the Lower Silurian. Prof. Lesquereux has quite recently received from Cincinnati a fine specimen of *Calamites* (*Bornia*) *radiatus*. Figs. 168 and 168*a* are from the Helderberg (Upper Silurian) sandstone of Michigan.

79,

R. 79

CHAPTER X.

Upper Silurian.

110. **The Upper Silurian rocks** extend upward from the top of the Cincinnati Group to the top of the Oriskany sandstone, including, in the ascending order, the *Clinton*, *Niagara*, *Salina*, *Lower Helderberg*, and *Oriskany* groups.

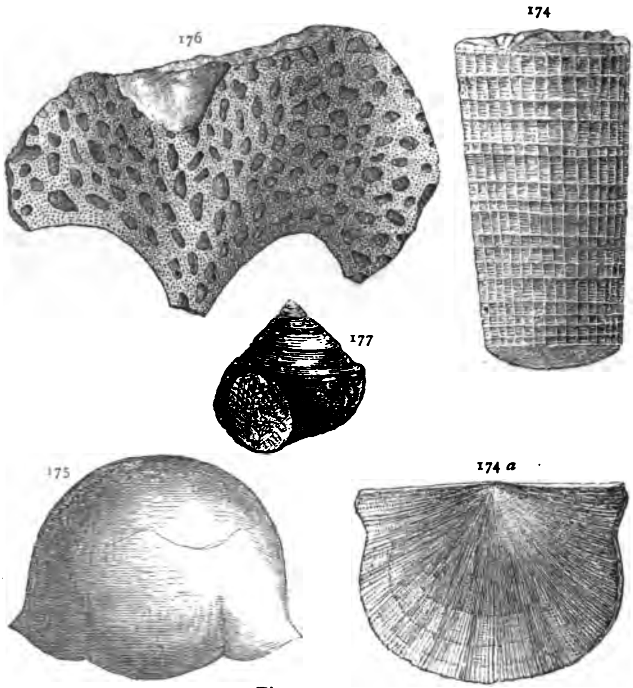
In the Interior States, the series is shown in the following section, Fig. 173.

111. **The Clinton rocks,** which have sometimes been included in the Niagara Period, rest directly upon the Cincinnati Group in Ohio, Indiana, and Kentucky. In Wisconsin, a bed of iron ore, from 6 to 15 feet thick, is supposed to be in the Clinton formation. The formation is elsewhere generally marked by a peculiar bed of iron ore, usually known as the "Clinton ore." This ore has an extended range through Pennsylvania, Virginia, Tennessee, and Alabama. In West Virginia, rocks of the Clinton Epoch are found in Hampshire and Hardy counties, while the Medina sandstone, which, in New York, underlies the Clinton, but has not been identified with certainty in the West, is in

Fig. 173.

large development in Pendleton County, and along the North Fork of the South Branch of the Potomac River.

112. Fossils of the Clinton group.—The following are a few of the Clinton animal fossils.



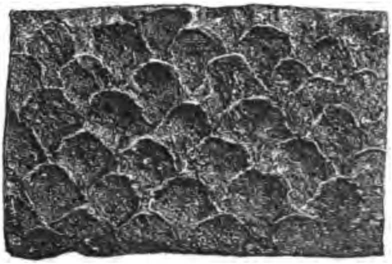
Figs. 174-177.

Fig. 174, Orthoceras Jamesi; 174*a*, Strophomena patenta; 175, Illænus Daytonensis; 176, Clathropora Clintonensis; 177, Pleurotomaria inexpectans.

113. Plants.—Quite recently Prof. Claypole has discovered, in the Clinton rocks, in Preble County, Ohio, a most interesting specimen of a land plant, closely allied to the Lepidodendron of the Coal-measures. This is shown in Fig. 178.

It will be remembered that other land plants have been discovered in the Cincinnati Group, at Cincinnati, and at Lebanon, Ohio. The finding of these plants along the range of the Cincinnati anticlinal, suggests the probability of a land surface, some where along the line of this uplift, on which the plants grew. They probably drifted from the place of growth, but some of them are so small and delicate that they could hardly have come from the old Archæan lands far to the north.

Fig. 178.



Glyptodendron Eatonense.

114. Niagara Epoch.—Immediately above the Clinton rocks are those of the Niagara Epoch, a group of wide extent, and found in nearly all of the Interior States. In Ohio, Kentucky, and Indiana, this group forms a marginal belt, bordering the rocks of the Cincinnati Period. The Niagara rocks are chiefly limestones and shales, and contain many forms of marine animals and plants. The name is derived from Niagara, New York, where, at the Falls, the rocks of this Epoch form the larger portion of the cliffs. The upper part is a hard limestone, while the lower is a soft shale. This under shale is easily disintegrated and removed by the water, and the harder rock above, being

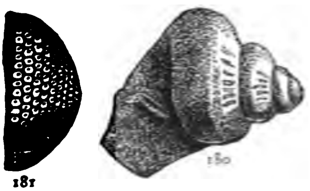
Fig. 179.

Dip of the Strata at Niagara Falls.

undermined, breaks off, and in this way the Falls move backward up the Niagara River. The two kinds of rock are shown in Fig. 179: *a* is the hard Niagara limestone; *b*, the softer Niagara shale. The dotted line indicates the probable future bed of the river. The Falls will disappear, and a long series of rapids take their place.

The Niagara limestone is found at Chicago, Illinois, where it has been quarried for building purposes. The rock is here sometimes saturated with petroleum. An old church, on Wabash Avenue, in the city of Chicago, unfortunately destroyed by the great fire, was almost black with exuding petroleum.

Figs. 180, 181.



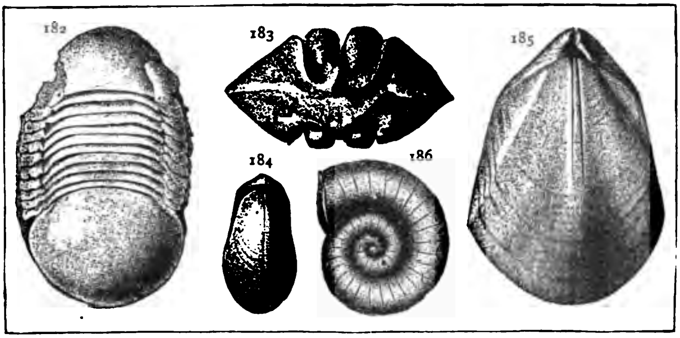
Niagara Group.
Fig. 180, Pleurotomaria Casii.
Fig. 181, Pasceolus dactylioides.

In the lead region of north-western Illinois, south-western Wisconsin, and north-eastern Iowa, the Niagara limestone directly overlies the Cincinnati Group. The Clinton Group is not seen.

The Niagara limestone forms cliffs on the Ohio River, in Adams County, Ohio. Dr. Locke, in the early geological survey of Ohio, called the formation the *Cliff limestone*. For some time this formation was confounded with the Devonian Corniferous limestone, and both were called the Cliff limestone. Prof. Winchell determined, from fossils collected by the author, that the Cliff limestone of Adams County was Niagara, and, at the same time, from other fossils, determined the underlying beds to be of Clinton age.

115. **Salina Period.**—The rocks of the Onondaga Salt Group of New York belong to this period. From this Salt Group large quantities of salt are made near Syracuse, New York. The Salina shales of New York are a thousand feet

Figs. 182-186.



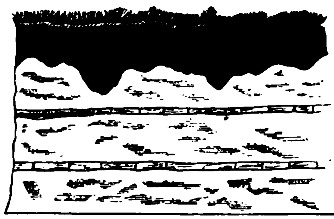
Fossils of the Niagara Limestone.

Fig. 182, Illænus insignis; 183, Trimerella Ohioensis; 184, Meristella cylindrica; 185, Pentamerus oblongus; 186, Lituites (?) Ortoni.

The Cystid, Apiocystis Gebhardi, Fig. 48, page 54, is found in the Niagara limestone.

thick, but thin out to the westward to 20 feet, in Ohio, and 40 feet, in Michigan. In Ottawa County, Ohio, the Salina affords valuable beds of gypsum, or plaster of Paris, as shown in Fig. 187. In Michigan a portion of the group is a gypseous marl. The formation is seen at Point aux Chênes, and at other places along the margin of the Lake, often beneath the water. Salina beds are found also in Monroe County. Where the beds of this Period come to the surface in Michigan, no salt is found; but borings at Caseville and Alpena penetrated a thick bed of rock salt, which is thought by Prof. Winchell to be the equiva-

Fig. 187.



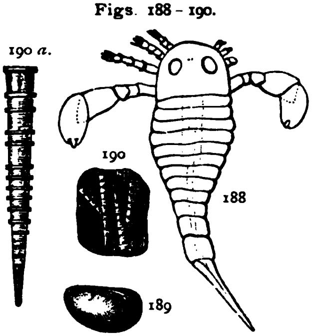
Gypsum Beds, Ottawa County, Ohio.

lent of the bed at Goderich, on the opposite side of Lake Huron, in Canada.

116. Lower Helderberg.—The rocks of this period were first studied in the Helderberg Mountains, south of Albany, New York. There was also, in the same mountains, a group called the Upper Helderberg, but this was found to belong to the Devonian Age, and the term Upper Helderberg has been dropped, while that of Lower Helderberg is retained for a group of Upper Silurian rocks.

In the Interior States, the principal bed of the group is the *Water-lime* formation, so named from the fitness of the limestone for making water-lime, or hydraulic cement, which, in mortar, "sets" or hardens under water. In Ohio the Water-lime is found on both margins of the Cincinnati uplift, and over a large area forms the central or highest rock of the arch. It is seen at Put in Bay Island, in Lake Erie, at Greenfield, Ohio, and at many other points in Ohio and Indiana.

Figs. 188-190.



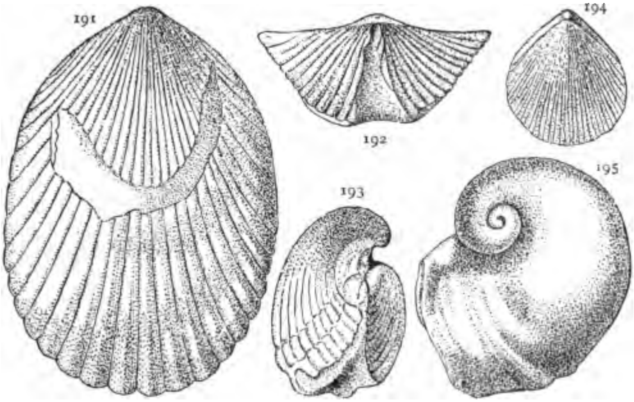
Fossils of the Water-lime.
Fig. 188, Eurypterus remipes.
Fig. 189, Leperditia alta.
Fig. 190, Tentaculites irregularis.
Fig. 190 *a*, Same magnified.

117. Fossils.—The three most characteristic fossils are shown in Figs. 188–190.

118. Oriskany Period.—The rocks of this period are assigned to the Upper Silurian by Prof. Hall, and they are so classified by Prof. Dana, but many geologists assign them to the Devonian Age.

The Oriskany rocks, chiefly sandstones, are found in several of the Interior States. In Ohio, a thin band of sandstone, supposed to be of the Oriskany Period, overlies

Figs. 191 - 195.



Fossils of the Oriskany.

Fig. 191, Rhynchonnella speciosa; 192, 193, Spirifer hemicyclus; 194, Eatonia peculiaris; 195, Strophostylus (?) cancellatus.

the Water-lime. No fossils have as yet been discovered in it. It is also found in Indiana. In southern Illinois—in Alexander, Union, and Jackson counties—are Oriskany sandstones and shales, containing several characteristic fossils. The same formation is reported in Ste. Genevieve and Ralls counties, Missouri. Oriskany rocks, in heavy development, are found in the mountains in Hampshire, Hardy, Pendleton, and Pocahontas counties, in West Virginia.

119. Oriskany Fossils.—Some of the fossils of the Oriskany are seen in Figs. 191–195.

120. Plants of the Upper Silurian.—One land plant, from the Clinton rocks of Ohio, has already been noticed in this chapter. Dr. Rominger has found land plants in the Upper Silurian (Helderberg) of Michigan, which are seen in figures 168 and 168*a*, on page 115.

Dr. Dawson has described several land plants from the

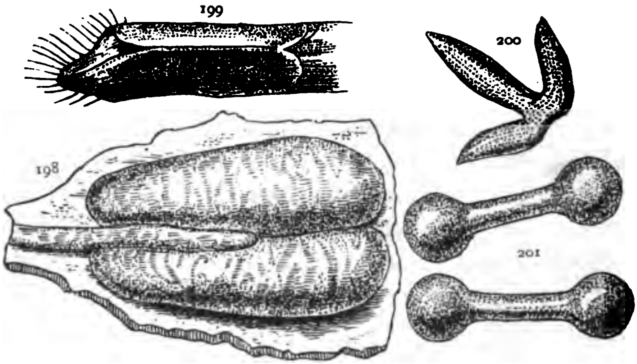
Upper Silurian of Gaspé, Canada, two of which are given in Figs. 196 and 197.

Figs. 196, 197.

Fossils of the Upper Silurian, of Gaspé, Canada.

Fig. 196, Psilophyton princeps; 197, Psilophyton robustius.

Marine Plants are often found in the Upper Silurian rocks. Some from the Clinton rocks are given in Figs. 198–201.



Figs. 198-201.

Fig. 198, Rusophycus bilobatus; 199, Palæophycus striatus; 200, Ichnophycus tridactylus; 201, Roots.

Fig. 198 was supposed, by Prof. Hall, to be a sea-weed, but some regard it as a cast of the track of an articulate. The fossils shown in Fig. 201 are supposed to be roots of sea-weeds.

CHAPTER XI.

Devonian Age.

121. The Devonian Age follows the Silurian. It is divided into four Periods, in the ascending order, as follows: *Corniferous*, *Hamilton*, *Chemung*, and *Catskill.*

Rocks of all these periods, unless it may be of the Catskill, are found in the Interior States. Catskill rocks are supposed to exist in West Virginia.

Fig. 202.

Section of Devonian Rocks.

122. Corniferous.—The Corniferous rocks are the lowest in the series, and consequently the oldest. The name is derived from the flint, or *hornstone*, often found in the limestones of this period.

Corniferous rocks are found in Ohio, Kentucky, Indiana, and Illinois, and may exist in other Interior States, but have not as yet been separated from the Hamilton rocks which overlie them. Limestones chiefly compose the formation, and in many places afford a suitable building material. When not too flinty, the stone yields excellent lime. The large and costly State House, at Columbus, is built of this limestone, from quarries near that city.

123. Fossils of the Corniferous.—*Land plants* are not numerous, but doubtless there was no lack of vegetation

on the land bordering the Corniferous seas. Few plants were preserved, and of these, probably, only a small number have been found. Fig. 203 represents the stalk of a

Fig. 203.

Caulopteris antiqua.
(Reduced.)

Fig. 204.

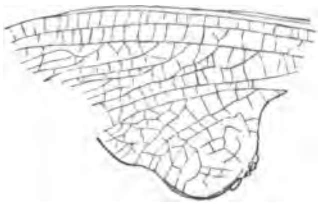
Psilophyton princeps.
Species characteristic of the whole Devonian series of N. A.
a, Fruit, one half natural size.
b, Stem, one half natural size.

large fern, *Caulopteris antiqua*, found in a limestone quarry, at Sandusky, Ohio. Another species of the same fern, *Caulopteris peregrina*, has been found in Ohio. A fragment of Lepidodendron has been found at Sandusky. Large silicified fragments of coniferous (cone-bearing) wood have been found in the Corniferous limestone. They had floated from the land and were buried in calcareous mud, in the bottom of the sea. It is thus interesting to note that in the lowest division of the Devonian rocks, in the Interior, we find representatives of three distinct botanical groups—Ferns, Lycopods, and Conifers.

In Fig. 204 we have a very characteristic Devonian plant, from Canada, the *Psilophyton princeps*, described by Dr. Dawson. The same author reports a large number of plants from the Devonian rocks of Canada. These are Ferns, Calamites, Sigillariæ, Lepidodendra, etc., an assemblage of plants closely allied to those of the more abundant vegetation of the Coal-measures.

Many species of *Spirophyton* (see Fig. 233, page 137), a marine plant, are reported from the Corniferous limestone at Sandusky.

Fig. 205.



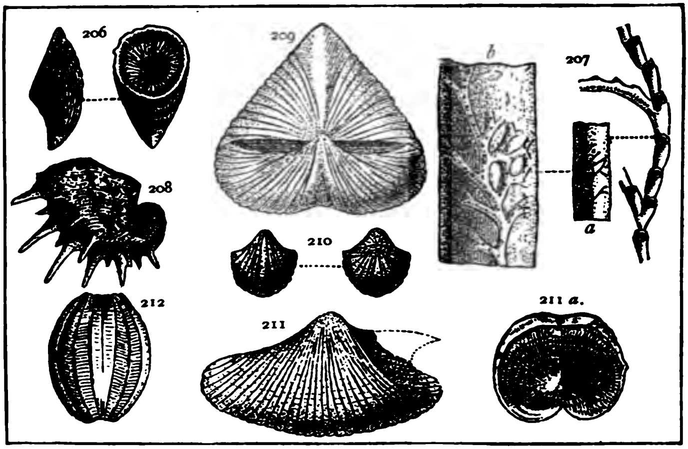
Wing of Platephemera.

In the Devonian marshes there were insects of large size, allied to the modern May-flies, the larvæ of which lived in the marshy waters. The wing of another kind (Fig. 205) has been found, somewhat akin to the grasshopper tribe. This latter insect was capable of making a cricket-like noise—"the oldest music of living things that geology reveals to us," says Dr. Dawson. But since land plants have been found in the Lower Silurian, we may hope to find proofs of the existence of insects during that very ancient period.

The hornstone, in the Corniferous limestone, is made up of minute silicious forms of plants and animals. The plants are microscopic, some of them not more than one five thousandth of an inch in diameter. Similar plants, called Diatoms, or Protophytes, are now growing so abundantly in some waters that large accumulations of the silicious shells are formed.

The Tripoli polishing powder of Bilin, Bohemia, contains, according to Ehrenberg, 41,000 millions of Diatoms in a cubic inch.

124. The animal fossils of the Corniferous are abundant. A few of them are represented in Figs. 206–212.



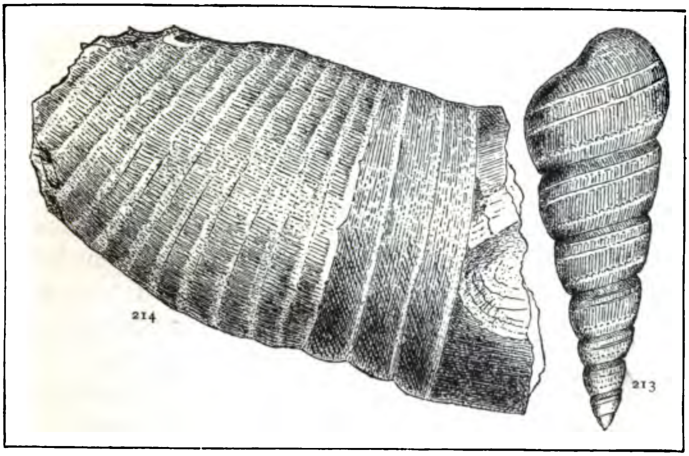
Figs. 206–212.

Fig. 206, Cystiphyllum Ohioense, ½ natural size; 207, Aulopora arachnoidea; 207 *a*, natural size; *b* and *c*, enlarged; 208, Platyceras dumosum, ½ natural size; 209, Spirifer acuminatus, ⅔ natural size; 210, Spirifer gregarius, ⅔ natural size; 211, Conocardium trigonale, ⅔ natural size; 211 *a*, end view of same; 212, Nucleocrinus Verneuili, ⅔ natural size.

Many of the above forms are very common in the Corniferous rocks of Ohio.

The *Spirifer acuminatus* (Fig. 209) is one of the finest and most characteristic of the formation. The *Conocardium trigonale* (Fig. 211) is another characteristic shell. The pretty little Crinoid, *Nucleocrinus Verneuili* (Fig. 212), is often found. It has no arms like most of the Crinoids. The Corals of this formation are in places exceedingly numerous, suggesting the idea of old Coral reefs. Such a reef is seen at the Falls at Louisville, Kentucky.

Fig. 213, 214.



Fossils of the Corniferous.

Fig. 213, Orthonema Newberryi; 214, Cyrtoceratites Ohioensis.

The *Cyrtoceratites Ohioensis* is interesting, as showing a portion of the outer shell. It is seldom that the outer shell is preserved in this group of fossils.

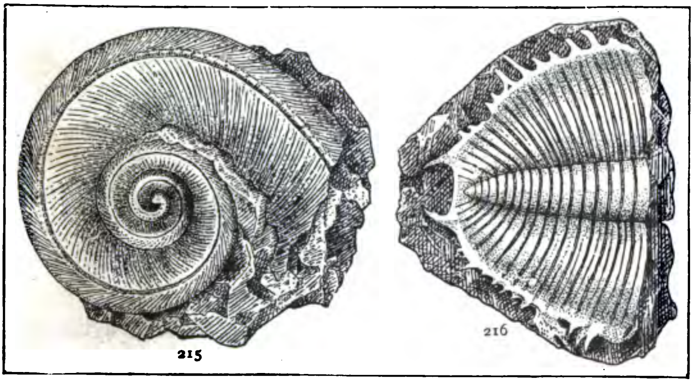


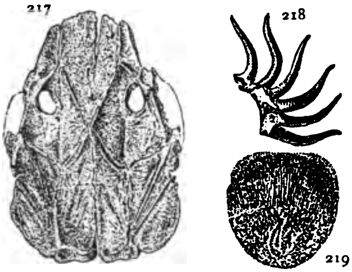
Fig. 215, 216.

Fig. 215, Euomphalus Decewi; 216, Dalmanites Ohioensis.

125. Fossil Fishes of interesting forms are found in the Corniferous limestone. Fig. 217 represents the head of a *Macropetalichthys Sullivanti*, from Columbus, Ohio. The most remarkable feature of this fish is the firm bony head, composed of many hard plates. These were covered with a thick skin, dotted with little star-shaped tubercles. Heads have been found fifteen inches long.

In Fig. 218, we have the teeth of another fish from the Corniferous seas, the *Onychodus sigmoides*. A scale of the same fish is given in Fig. 219. Fragments of other forms of fishes have been found in the Corniferous rocks of Ohio.

Fig. 217 - 219.



Fishes of the Corniferous.

Fig. 217, Head of Macropetalichthys Sullivanti, one fifth natural size; 218, Teeth of Onychodus sigmoides, one half natural size; 219, Scale of latter, one half natural size.

126. Hamilton Period.—Rocks of the Hamilton Period are found in most of the Interior States. In Ohio, they are thin limestones and shales, not easily separable from the Corniferous. In Michigan, they are believed to constitute the Little Traverse Group of Prof. Winchell.

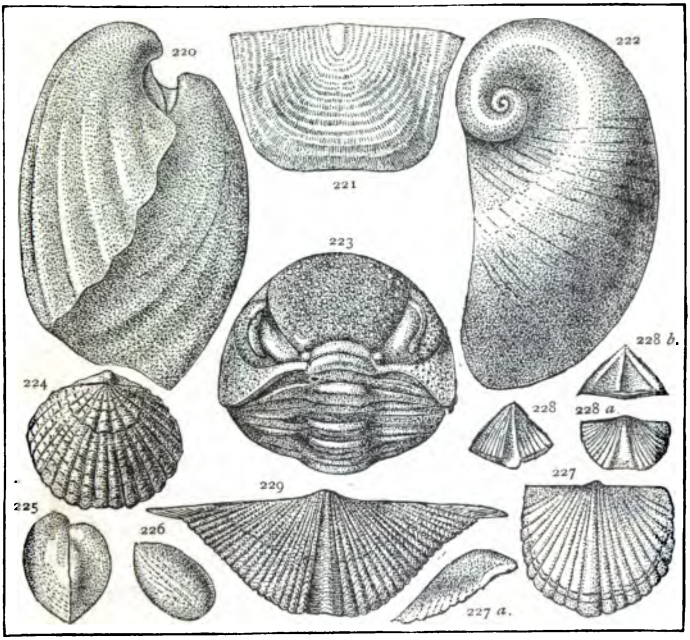
In Iowa, beds of the Hamilton Period constitute the whole of the Devonian formation. They extend in a broad belt from Davenport and Muscatine, in a north-west direction, to the north line of the State in Worth and Mitchell counties. They are about 200 feet thick.

In Illinois, opposite Davenport, Iowa, there is a limited area of Devonian rocks, including the Hamilton. There are two other small patches of Devonian, one near the mouth of the Illinois River, and the other a little west of

Jonesboro. The greatest thickness of the Hamilton, with the included underlying Corniferous, is 120 feet. In Missouri, the Hamilton beds, including a lower Onondaga limestone, are about 100 feet thick.

In West Virginia, rocks of the Hamilton Period, chiefly clays and shales, attain a great thickness in the Alleghany Mountains. Prof. Fontaine attributes the waters of the famous sulphur springs of West Virginia to these rocks.

Figs. 220-229.



Fossils of the Hamilton Group.

Fig. 220, Spirifer subundiferus; 221, Strophomena rhomboidalis; 222, Platyceras ventricosum; 223, Phacops rana; 224, Atrypa aspera; 225, Pentamerus subglobosus; 226, Lingula subspatulata; 227, 227 *a*, Tropidoleptus carinatus; 228, 228 *a*, 228 *b*, Cyrtina triquetra; 229, Spirifer mucronatus.

127. Devonian Black Shale.*—Overlying the Hamilton rocks, we find, in many of the Interior States, a remarkable formation of black bituminous shale.

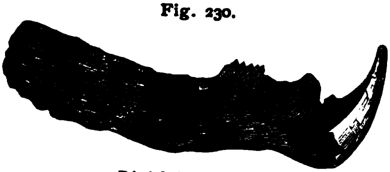
It is 300 feet thick in Ohio, but is generally thinner in the other states.

In Ohio, the Black Shale extends from Lake Erie, east of Sandusky, south to Buena Vista, on the Ohio River. In Kentucky, it every-where accompanies the Devonian rocks. It is found in Illinois, and perhaps in Missouri, but Prof. White denies its existence in Iowa.

The Black Shale derives its dark color from bituminous matter, of which it contains from 10 to 15 per cent. As the shale was originally mud in the ocean bed, the bitumen must have been derived from vegetable or animal matter in a comminuted or macerated form. Remains of fishes and a few shells have been found, but fossils are not numerous.

128. Fossils of the Devonian Black Shale.—A fish called *Dinichthys Herzeri* (or Herzer's terrible fish) was a formidable monster, nearly 20 feet long, with an immense head and jaw. A lower jaw is seen in Fig. 230. It had a large curved tooth at the end, which added much to the destructive power of the fish. Another species of the same fish, known as the *Dinichthys Terrelli*,

Fig. 230.

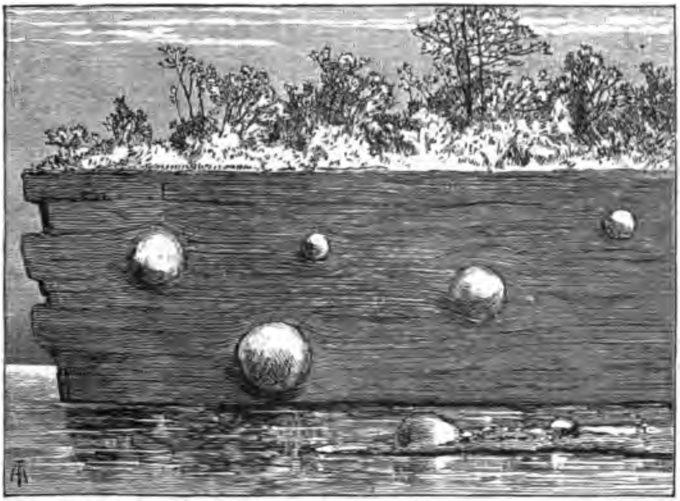


Dinichthys Herzeri.

* Note.—The Black Shales, with some overlying Portage and Chemung rocks, in Michigan, constitute the *Huron Group* of Prof. Winchell. In Ohio, Dr. Newberry calls the Black Shale, taken by itself, the Huron Shale. It being generally known, throughout the Interior States, as the Devonian Black Shale, that name is here retained.

equally as large as the *Dinichthys Herzeri*, has been found in the Black Shale, in Lorain County, Ohio.

We often find in this shale large concretionary balls of impure limestone. Some of these are several feet in diameter. They are represented in Fig. 231.



Figs. 231.

It was in breaking such balls that Rev. H. Herzer found the bones of his "terrible fish."

129. The Devonian Black Shale yields oil by distillation, and it is supposed by some to be the source from which much of the natural oil, or petroleum, of the country has been derived, by a slow process of subterranean distillation. Oil springs and gas springs are not uncommon in the sandstones overlying the Black Shale. In north-eastern Ohio, wells are bored into the Black Shale to obtain gas, which is used in warming and lighting dwellings.

The oil wells of Enniskillen, western Canada, and at Terre Haute, Indiana, are believed to obtain their oil from

the Corniferous limestone. It may be added that petroleum is found in many different geological formations.

130. **Chemung Period.**—Rocks of this period are not abundant in the Interior States. They are New York rocks, and thin out to the west and south-west. They reach the mountain region of West Virginia, where they are probably 2,000 feet thick. In north-eastern Ohio, they are represented by the *Erie Shales*, from 500 to 1,000 feet thick, and in Michigan they are reported to have a total thickness of 700 feet; but they are not known to exist in any states farther west or south-west.

131. **Catskill Period.**—Rocks of this period, if found at all in the Interior States, must be looked for in the mountains of West Virginia, associated with the rocks of the Chemung Period. As yet they have not been identified with certainty.

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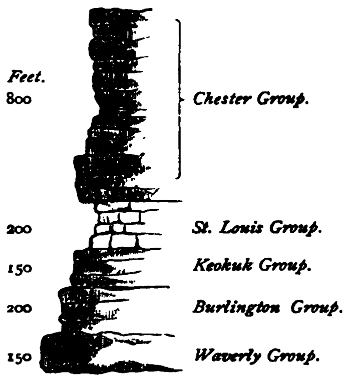
CHAPTER XII.

Lower Carboniferous.

132. The Carboniferous Age derives its name from the large quantity of carbon, in the form of coal, found in its rocks. It is divided into three Periods: *Lower Carboniferous*, *Coal-measures*, and *Permian*.

133. Lower Carboniferous Rocks. — The rocks of this period are remarkably well developed in the Interior States, and contain large numbers of fossils of great interest and beauty. The only states destitute of rocks of this period are Wisconsin and Minnesota, the formations in these states, below the surface drift, being older than the Carboniferous.

Fig. 232.



Lower Carboniferous Rocks.

Perhaps the best development of the Lower Carboniferous series is in Illinois, where we find in all 1,500 feet of strata, divided into five groups or epochs, named in the descending order — *Chester*, *St. Louis*, *Keokuk*, *Burlington*, and *Waverly*. They are shown in Fig. 232.

The lowest of the group is the Waverly, so named by the early Ohio geologists from the town of Waverly, on the Scioto River, in Ohio, where the sandstone is quarried. The names which have been since given to the group are *Kinderhook*, in Illinois and Iowa; *Chouteau*, in Missouri; *Marshall*, in Michigan; and *Knobstone*, in Kentucky and Indiana.

In Ohio, the Waverly sandstones and shales are 600 feet thick. The better sandstone layers are fine grained, of handsome bluish drab color, and are much prized for building stone: the most famous quarries being at Buena Vista, on the Ohio River; Waverly, in Pike County; and Berea and Amherst, in Lorain County.

The Waverly rocks extend south from Ohio through Kentucky into Tennessee, bordering the west side of the Alleghany coal-field. In Kentucky, where the south-eastern portion of the great Middle coal-field is nearest to the Alleghany field, the Waverly rocks stretch across the interval, and extend northward into Indiana, along the east side of the Middle coal-field.

In lower Michigan, the Waverly—called by Prof. Winchell the Marshall Group, but Waverly by Dr. Rominger—forms one of the several concentric geological belts, which have for their center the Michigan coal-field.*

In Illinois, the Lower Carboniferous series, of which the Waverly, or Kinderhook, Group, is the lowest member, extends from the southern portion of the state in a belt along the Mississippi River, or a little east of it, and crosses that

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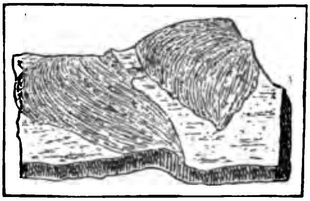
*NOTE.—It should be stated that Dr. Rominger, in his recent geological map of Michigan (Lower Peninsula) extends the Waverly from the Coal-measures to Lake Michigan. The Devonian belt will then be found under the lake. A little patch of this belt is found west of the lake, near Milwaukee.

river between Burlington and Muscatine. Thence the belt stretches in a north-west direction through Iowa. In Henderson, Pike, Calhoun, and Jersey counties, Illinois, the Waverly has a thickness ranging from 150 to 250 feet. It is thinner in Iowa.

In Missouri, the Waverly includes the Chouteau limestone, the Vermicular (worm-marked) sandstone, and the Lithographic limestone. Prof. Swallow reports the aggregate thickness of all the beds at 285 feet.

134. **Plant Fossils of the Waverly.**—The Plants are chiefly marine. One of the most abundant of these is the *Spirophyton*, or spiral plant. These are very abundant in Ohio, and Kentucky.

Fig. 233.

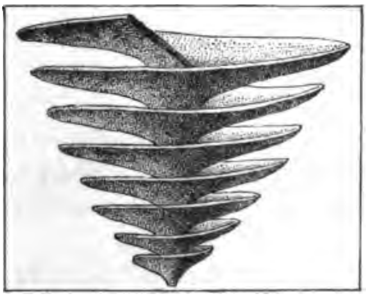


Spirophyton cauda-galli.

Fig. 233 represents fragments of two leaves of *Spirophyton cauda-galli*, one eighth natural size. This is a very common species.

Prof. Hall has restored from the study of the fragments the form of another species, which he calls *Spirophyton typum*. The leaves form a continuous whorl, enlarging from the bottom of the plant. See Fig. 234.

Fig. 234.



Spirophyton typum (restored).

The Spirophyton has a wide range in the geological series, extending from the lower Devonian into the Coal-measures. It was a hardy sea plant, and found the conditions favorable to its growth during a long period.

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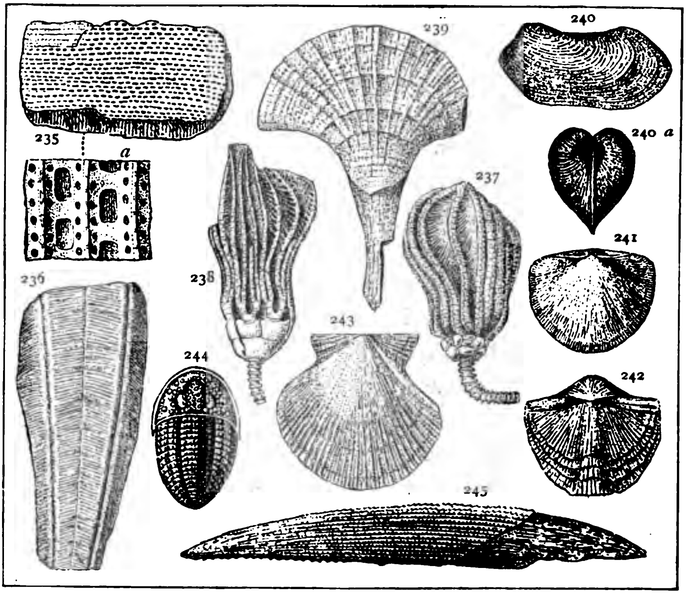
135. Animal Fossils of the Waverly.—Some of these are represented in Figs. 235–245, except 239.



Figs. 235-245.

Fig. 235, Fenestella delicata; 235 *a*, same, magnified; 236, Conularia micronema; 237, Actinocrinus helice; 238, Platycrinus Richfieldensis; 239, Dictyophyton Newberryi; 240, Alorisma Winchelli; 240 *a*, end view of same; 241, Hemipronites crenistriatus; 242, Spirifer striatiformis; 243, Aviculopecten Winchelli; 244, Phillipsia lodiensis, enlarged; 245, Ctenacanthus triangularis.

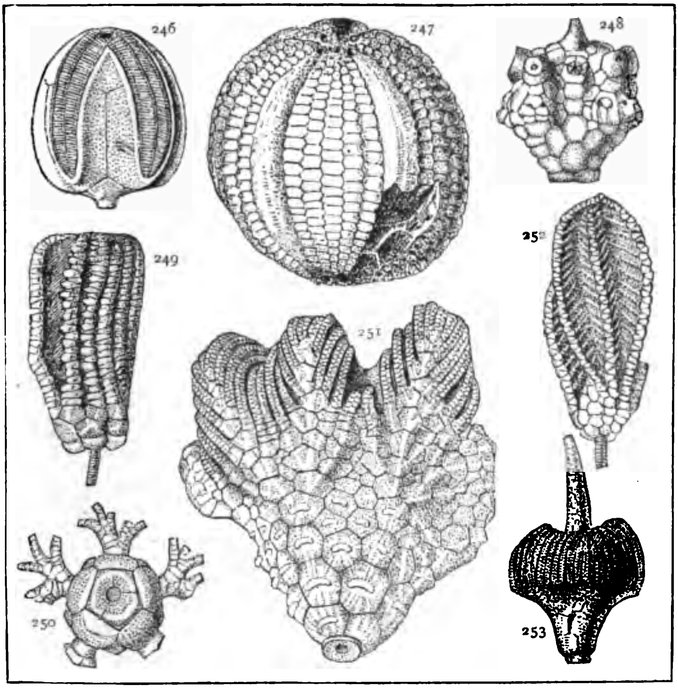
136. Burlington Group.—Next above the Waverly comes the Burlington Group, chiefly limestones, named from Burlington, Iowa, where the rocks are well exposed, and where its fossils are very numerous.

From Burlington, the group extends to the north-west through several counties in Iowa. In Illinois it is found at Quincy, and in a few counties along the Mississippi River.

The group appears in Missouri, forming, with other Lower Carboniferous rocks, a belt bordering on the Coal-measures. The Burlington lime-stone, in Missouri, is called, in some of the Reports, the *Encrinital* limestone, from the remains of crinoids or encrinites contained in it.

The most remarkable locality for crinoids in the world is doubtless the city and vicinity of Burlington, from which the

Figs. 246–253.

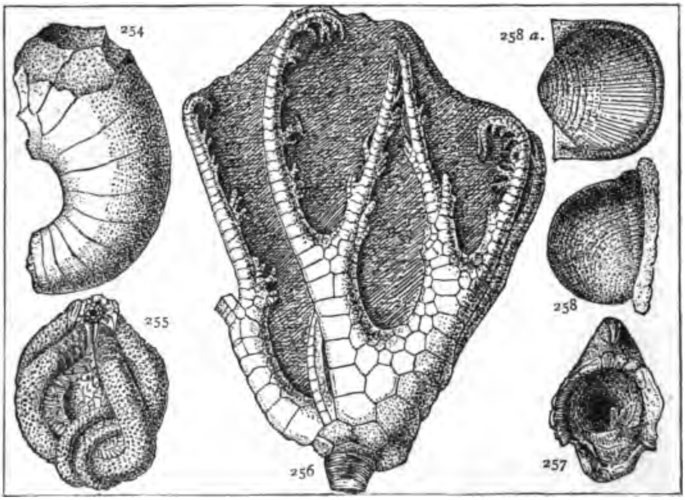


Crinoids from the Burlington Limestone.

Fig. 246, Pentremites Burlingtonensis; 247, Oligoporus nobilis; 248, Dorycrinus intermedius; 249, Scaphiocrinus rudis; 250, Platycrinites incomptus; 251, Strotocrinus perumbrosus; 252, Scaphiocrinus scalaris; 253, Batocrinus Chrystyi.

group is named. Here one person, Mr. Charles Wachsmuth, had, some years since, collected 355 species, representing 44 genera, and he is still finding new forms. The old ocean bed must have been covered with these stone lilies—not plants, but animals—attached to the bottom by long, jointed, flexible stems. They belonged to the Radiates.

Figs. 254-258.



Fossils of the Keokuk Group.

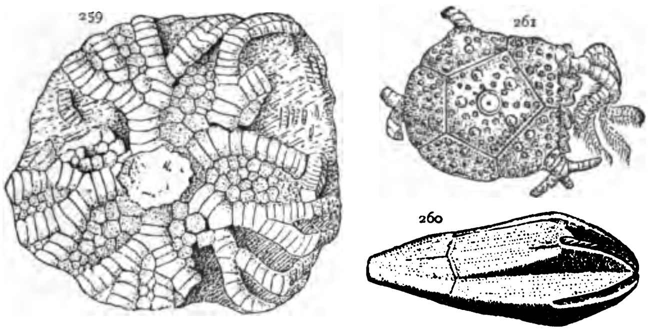
Fig. 254, Nautilus ——? 255, Onychaster flexilis; 256, Onychocrinus exculptus; 257, Platyceras equilatera; 258, Productus Wortheni, profile view; 258 *a*, same, ventral valve.

137. Keokuk Group.—The limestones of this group rest upon the Burlington limestones, and resemble the latter in their general appearance. They are exposed at Keokuk, a locality which has given the name to the group, and at other points in south-eastern Iowa; also in Illinois, Missouri, and Indiana.

In the Lower Peninsula of Michigan is a group of rocks called, by Prof. Winchell, the *Carboniferous limestones*, which, from its fossils, he assigns to the Keokuk Group of the Mississippi Valley. Under it is the *Michigan Salt Group*, which contains both salt and gypsum. The brine is obtained by boring and pumping, and large salt works are established on the lower Saginaw River. Gypsum is found at Grand Rapids and at Alabaster, on Saginaw Bay, where considerable quantities are quarried. Prof. Winchell thinks the Salt Group only a local condition of the lower portion of the Carboniferous limestone formation. Dr. Rominger regards the Salt Group as a portion of the Waverly. In Ohio, the Waverly is the chief salt-bearing formation, and the salt wells pass through the Coal-measures into the Waverly below.

At Crawfordsville, Indiana, the Keokuk rocks are very rich in fossils, and many new and beautiful forms of Crinoids have been obtained, a few of which are here given in Figs. 259–261.

Fig. 259–261.



Crinoids of the Keokuk Group.

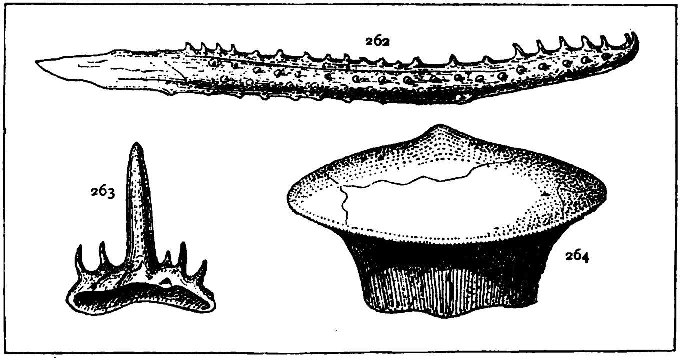
Fig. 259, Forbesiocrinus Wortheni; 260, Pentacrinites Wortheni; 261, Platycrinus hemisphericus.

138. St. Louis Group.—The rocks of this group, chiefly limestones, take their name from St. Louis, where they are found. They appear at Alton, Warsaw, and other points in Illinois. Formerly the *Warsaw limestone* was designated as a distinct formation, but it is now included in the St. Louis Group.

In Iowa, the St. Louis is the first group below the Coal-measures, the Chester Group being wanting. The group appears also at Bloomington and Spergen Hill, and at other points in Indiana, and is somewhat widely spread in Kentucky.

The Maxville limestone of Ohio contains some fossils of the St. Louis Group, but is usually classed with the Chester.

Figs. 262–264.

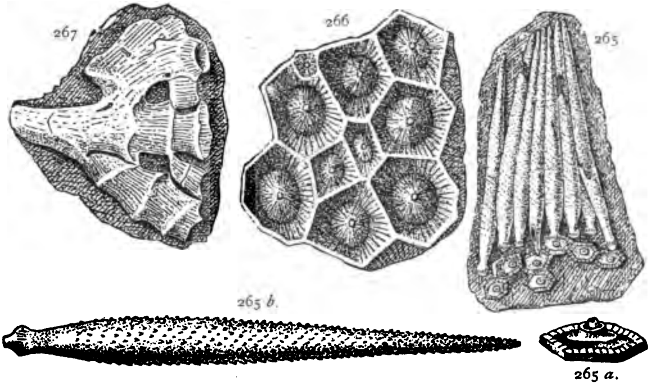


Fossil Fishes.

Fig. 262, Maracanthus rectus; 263, Cladodus excentricus; 264, Petalodus hybridus.

139. Fossils.—Like the other Lower Carboniferous rocks of the Interior States, this group abounds in fossils.

Fig. 262 represents a spine of a fish; 263 and 264 represent teeth of fishes. In Figs. 265, 265 *a* and *b*, we have plates and spines of an Echinoderm. Figs. 266 and 267 are Corals.



Figs. 265-267.

Fig. 265, Archæocidaris Agassizi—a fragment preserving several plates of the body, with a small group of spines; 265 *a*, profile view of a plate; 265 *b*, a single spine, slightly enlarged; 266, Lithostrotion mammilare; 267, Lithostrotion proliferum.

140. Ores in St. Louis and Keokuk limestones.— In Hardin County, in southern Illinois, and in Livingston, Crittenden, and Caldwell counties, in Kentucky, ores of lead and zinc are found in the rocks of the St. Louis Group. They are generally associated with fluor spar. The ores are in fissures, some of which are connected with "faults," and hence the veins are thought to be "true" veins. Other fissures are quite limited in extent, and are thought to be "crevice" or "gash" veins, like those in the lead region of Galena and Dubuque, which have been described on page 107.

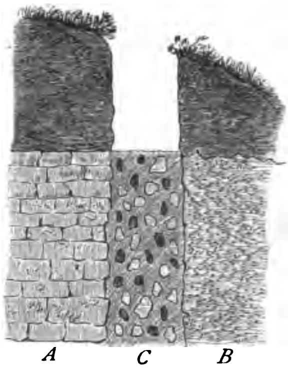


Fig. 268.

One of the oldest lead mines in Kentucky is the Columbia Mine, in Crittenden County. Fig. 268 represents the Glass Shaft of this mine.

Fig. 269.

A, St. Louis limestone; *B*, sandstone on opposite side of fault; *C*, the fissure or vein, containing fluor spar, calc spar, galena (lead ore), and blende (zinc ore).

At Rosiclare, Hardin County, Illinois, similar veins of lead are found in the same limestone, which extends from Kentucky into Illinois. At Rosiclare, mining has been carried on, with more or less vigor, for nearly forty years, but no large amount of lead has been produced. The same is doubtless true of the Kentucky mines.

Fig. 270.

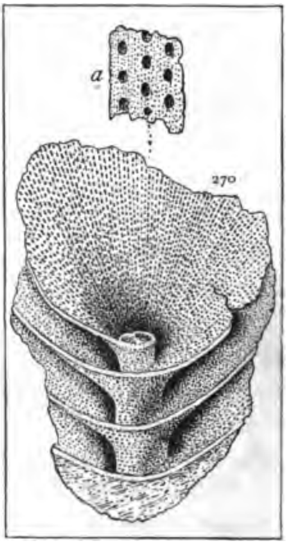


Fig. 270, Archimedes Wortheni.
Fig. 270 *a*, Same, magnified.

Much more productive mines of lead are found in south-western Missouri. The ore is associated with limestone and chert, believed to be of the age of the Keokuk Group. It is not in proper veins, but in pockets, or "runs," of all shapes, mingled confusedly with broken masses of limestone and chert. Fig. 269 represents one of these deposits of ore on Swindle Hill, in the Joplin lead district. *A*, solid limestone; *D*, soil and

clay; *B*, broken chert, with masses of chert at the bottom; *C*, sandy limestone, much decayed, with galena and blende.

A new area, very rich in lead ore, has recently been discovered a few miles south-west of Joplin. The zinc ores of south-western Missouri are now largely smelted.

141. The Chester Group.—This group is the upper member of the Lower Carboniferous Period. The name is taken from a town in Illinois. Rocks of this group are found in Illinois, Missouri, Indiana, Kentucky, and Ohio. They are generally limestones, but in some States, especially in Illinois, they are in part sandstones and shales. This group includes the *Pentremital* limestone, named from a crinoid with a five-sided stem, and the *Upper Archimedes* limestone, named from a screw-like coral found in it.

Fig. 271.

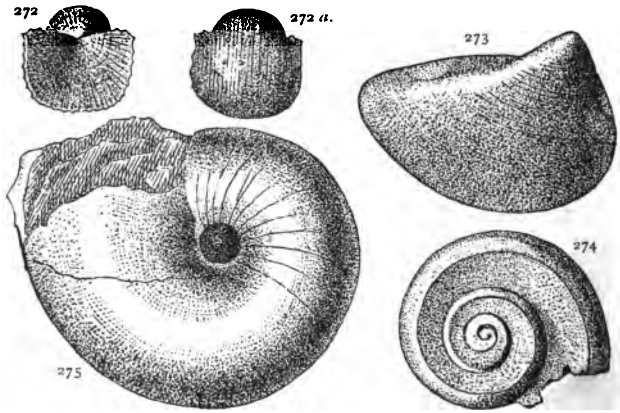
Figs. 270 and 270 *a* represent one of these corals, the *Archimedes Wortheni*, from Illinois. More often the thin portion is broken off, leaving a screw-like stem. We see here an animal whorl, while in the *Spirophyton typum* (Fig. 233, page 137) we saw a vegetable whorl.

In Ohio the Chester, or Maxville, limestone, never more than twenty feet thick, is found in a few isolated patches, which rest directly upon the Waverly, all the intervening groups (St. Louis, Keokuk, and Burlington) being absent. In north-eastern Kentucky the Chester also rests upon the Waverly, but in western Kentucky the St. Louis beds intervene.

In Illinois, all the Lower Carboniferous rocks thin out and disappear to the northward, and the northern margin of the coal-field rests upon rocks of Lower Silurian age; the Upper Silurian, Devonian, and Lower Carboniferous rocks all being gone.

142. Fossils.—The Chester Group contains many interesting fossils. Fig. 271 represents a curious tuberculated bone or spine of a fish, one half natural size, found at Newtonville, Muskingum County, Ohio.

Figs. 272-275.



Fossils of the Chester Limestone.

Fig. 272 and 272 *a*, Productus parvus; 273, Schizodus Chesterensis; 274, Straparollus planodorsatus; 275, Nautilus Chesterensis.

143. Caves in Lower Carboniferous limestones.—The Lower Carboniferous limestones of some of the Interior States are famous for their large caves. This is especially true in Kentucky, West Virginia, and Indiana. The region of these limestones in Kentucky, especially west of the line of the Cincinnati Southern Railway, is thus spoken of by Prof. N. S. Shaler: "It is characterized by having all its

smaller streams under ground, usually only the rivers over fifty feet wide at low water having their paths open to the sky. All this region wants the small valleys we are accustomed to see in any country, but in their place the surface is covered by broad, shallow, cup-like depressions or sink-holes, in the center of which is a tube leading down to the caverns below. . . . . Some idea of these underground ways may be formed from the fact that the Mammoth Cave affords over two hundred miles of chambers large enough for the passage of man, while the county in which it occurs has over five hundred openings leading far into the earth, none being counted where it is not possible to penetrate beyond the light of day."

This description of sink-holes and underground passages applies to the Lower Carboniferous limestones in West Virginia, Indiana, and doubtless to many localities in other Interior States.

True caves are found only in limestones. The so called caves in sandstone regions are generally recesses under shelving rocks, where the sandstone has been washed away, or its particles blown away by the winds. On the other hand, the limestone caves are made by the water dissolving away the rock, not wearing it away.

144. **Explanation of Caves.**—Rain and surface water always contain a little carbonic acid, which has the property of dissolving limestone. Such water passes down through crevices, and along the partings and cracks in the limestone,

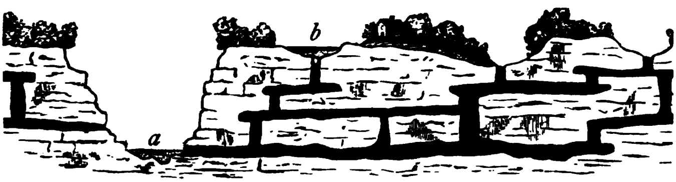


Fig. 276.

and dissolves away the edges and sides of the rocks, thus making, in the course of ages, large passage ways.

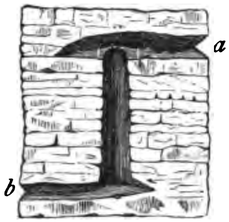


Fig. 277.

Fig. 276 represents such passage ways. The sink-holes are seen upon the surface, and their connection with the caves below; *b* is one which has had the outlet in the bottom filled with clay, to form a pond at which the farmer waters his stock; *a* is the lowest of the passages and has an outlet in the low valley on the left.

Some of these passages are vertical, others are horizontal. The water from above, finding a vertical fissure or shrinkage crack, descends, dissolving out a perpendicular shaft. These are sometimes circular, or nearly so, and of great depth, with the sides beautifully fluted, where little rills of water have passed down the walls. Such a shaft is shown in Fig. 277. The water descends from a higher passage, *a*, to a lower outlet at *b*.

Fig 278.

In the same way much larger pits are sometimes formed.

A part of such a pit is shown Fig. 278. If one should approach from the top, and look down into the dark abyss, he might well call it a "bottomless pit," as is done in the Mammoth Cave. If he stands in the bottom, and can illuminate the vast cavern, he finds it like a dome, with its top resting on immense fluted pillars, half carved from the solid rock. It is then a "mammoth dome," full of strange beauty.

Fig. 279.

In many caves the waters dripping from the roof form pendants of lime, like icicles. These are called *stalactites*. Where the dropping water strikes the floor, cones of lime are built up, called *stalagmites*. The two often unite and form pillars. Fig. 279 represents stalactites, stalagmites, and the natural pillars.

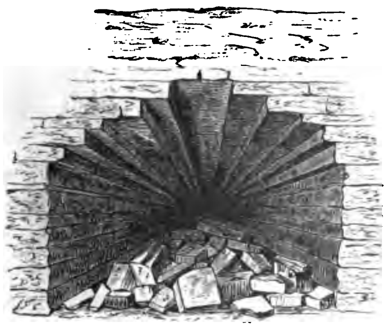


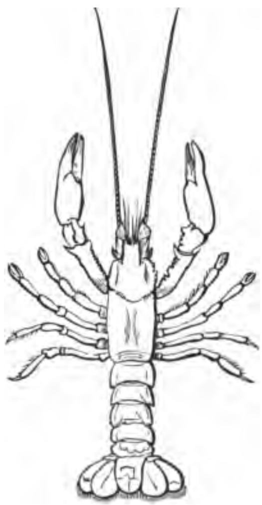
Fig. 280.

Sometimes caves are enlarged by the falling of the layers of limestone in the roofs. This is often the case where the rooms or passages are wide, and the layers overhead comparatively thin. Fig. 280 represents a pile of fallen rocks in a passage way. As is shown in this figure, the tendency is to form an arch, such as characterized the earlier and ruder days of architecture.

145. The Wyandotte Cave, in Crawford County, in south-western Indiana, is one of the most remarkable and interesting caves in the Interior States; it is in the St. Louis limestone. As yet it is only partially explored, but twenty-two miles of galleries are now known. Some of the rooms are of great size, and in this respect it excels the Mammoth Cave of Kentucky. In these vast rooms the center of the floor is piled with large masses of rocks, which have fallen from the roof.

Prof. Cope, who has visited this cave, thus describes the process of enlargement. "The destruction having reached the thin-bedded strata above, the breaking down has proceeded with greater rapidity, each bed breaking away over a narrower area than the one below it. When the heavily bedded rock has been again reached, the breakage has ceased, and the stratum remains, a heavy coping stone to the hollow dome. Of course, the process piles a hill beneath, and the access of water being rendered more easy by the approach to the surface, great stalactites and stalagmites are the result. The largest room is stated to be 240 feet high and 350 feet long, and to contain a hill 175 feet in height."

Fig. 281.



Cambarus pellucidus.

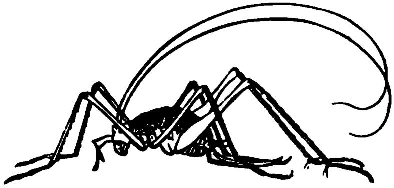
146. Animal Life in Caves.— We find in the caves many peculiar forms of animals — fishes, craw-fishes, and various insects. Many of these are blind, but show a rudimentary eye-structure. The eyes have evidently been lost by disuse in the darkness, and

there is a constant effort of Nature to restore them, for the young show the rudimentary structure more distinctly than the mature animals.

Fig. 281 represents a blind craw-fish, *Cambarus pellucidus,* from the Mammoth Cave, Kentucky.

Fig. 282 is a wingless grasshopper, *Rhaphidophora subterranea.* It is very common in the Mammoth Cave; and climbs the walls with great ease. It has perfect eyes, and the darkness of the cave has had, apparently, no effect to destroy them. All visitors to the cave must have seen this so-called "cricket" hopping about with great agility.

Fig. 282.



Rhaphidophora subterranea.

Coal Mine, Perry County, Ohio.

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CHAPTER XIII.

COAL-MEASURES.

147. HAVING noticed the Lower Carboniferous rocks, we pass upward, in the ascending series, to the COAL-MEASURES, or Carboniferous proper, from which the coal of the Interior States is obtained. Coal is found in nearly all of these States; viz., West Virginia, Ohio, Kentucky, Indiana, Michigan, Illinois, Missouri, and Iowa. It forms, however, only a small part of the whole series of rocks. These rocks are chiefly sandstones, shales, and limestones, as shown in the geological section, Fig. 283.

Near the bottom of the section is a seam of coal, in three parts or benches, separated by layers of clay and shale. Near the top is another seam, but between the two are many feet of other kinds of rocks.

148. **Origin of Coal.**— Coal was formed of plants, which grew in swamps and broad marshes. These marshes were low, and liable to be overflowed, for we find, in the associated shales, shells, and scales and bones of fishes. We often find such remains in cannel coals. The water in these swamps was doubtless sometimes brackish, and, perhaps, entirely fresh—low ridges of sand cutting off the inroads of sea water then, as they often do now from the flats and marshes along our coasts.

149. **Under-clay.**—We generally find, under each seam

of coal, a layer of compact clay, called under-clay. Some regard this clay as the soil in which the vegetation of the marsh grew, as it is generally filled with rootlets of the Stigmaria — a plant to be noticed hereafter. But the clay served another important purpose, in forming a retentive bottom to the marsh, and holding water enough to aid the growth of the plants, and also to cover and preserve the falling leaves and trunks of trees from rotting away, as they would have done in the air.

Fig. 283.

150. The Dismal Swamp, in south-eastern Virginia, is perhaps the best modern illustration of an ancient coal-marsh. There we find a wide marsh with a large mass of buried vegetable matter, upon the surface of which trees and various plants are growing. The water preserves the falling trees from decay, that is, from that kind of decay and waste which takes place when a fallen tree in our common forests rots away.

Fig. 284 represents a similar marsh of the coal period, except that the trees are quite different from those now growing in the Dismal Swamp: *a* represents the clayey bottom — the under-clay; *b*, the accumulated vegetable matter — the growth of many generations of trees and smaller plants.

At first, the trees were rooted in the ooze of the clayey

Fig. 284.

mud, for we find their roots there; afterwards, the roots of later generations of trees spread themselves in the increasing vegetable matter above the mud. Every year leaves, fronds, and trunks of trees were falling to add to the mass below. We find beautiful impressions of this vegetation—*Sigillariæ*, *Lepidodendra*, *Stigmariæ*, etc., now turned to coal—which grew in the ancient marshes and fell, year by year, to increase their beds. With the microscope, traces of vegetable fibres are every-where to be seen. Afterwards, each marsh settled down, as many sea coasts are now settling, and the waters brought in mud or sand, and buried the whole. When the downward movement had stopped, the filling up of the water over the former marsh area would continue until the surface was reached, when a new marsh would be formed with its coal-making vegetation.

This is briefly the history of each seam of coal in the Coal-measures. Each seam represents a petrified marsh. Where the subsidence was regular and uniform over large areas, the seams of coal—each representing a level marsh on or near the water-line—would be brought into a series of nearly parallel bands, and thus a systematic grouping of the coal seams is made possible.

When a marsh settled down in comparatively quiet water, a sediment of fine mud would be spread over it. In this mud, which afterwards hardened into shale, would be buried the trees and plants last growing upon the surface. Such trees and plants we find, often very beautifully preserved. The larger trees, surrounded by the water, in time rotted and fell, and were buried as prostrate trunks, and we now find

them flattened in the roof shales of our coal mines. Sometimes such trees continued standing while sand came in around them, and have thus left their casts in the sandstones. Great numbers of the trunks of such erect trees have been found over seams of coal in the South Joggins, in the cliffs bordering the Bay of Fundy. The seams of coal are now inclined, but the trunks stand at right angles to the planes of the seams, thus showing that they grew from the coal marshes when the latter were horizontal.

Fig. 285.

Section, South Joggins, Nova Scotia.

These trunks are shown in Fig. 285. One trunk, reported by Sir Charles Lyell, who visited this region, "was 25 feet high, and 4 feet in diameter, with a considerable bulge at the base." In the decay of these trees, the bark was the most durable part, and remained as a hollow cylinder. These hollow trunks were filled with mud and sand. In one of them Dr. Dawson found a land snail, and bones of an air-breathing reptile (*Dendrerpeton Acadianum*).

Fig. 286.

Sigillaria Oweni.

Fig. 286 represents a stump of one of the coal trees (*Sigillaria Oweni*), found in a railway tunnel in Athens County, Ohio. It is four and one half feet high, with a circumference at the base of five feet nine inches. It is

a cast in sandstone, but the bark had been preserved and turned into a thin film of coal, retaining the original bark markings. The conversion, in similar cases, of the bark into coal, while all the wood of the tree has disappeared, has suggested to Dr. Dawson the idea that the coal of coal seams was largely formed from the bark of coal trees. He points to the durability of the bark of modern trees after the decay of the wood, giving as an instance the birch (*Betula papyracea*). The author, in exploring ancient mounds on which no trees have grown for fifty years, has found, near the bottom of the mounds, roots of trees and plants that once grew on them entirely decayed, except a thin film of the outer covering. Some of these were small rootlets, but the film of bark, as thin as tissue paper, remained firm. 79

151. Many blocks of coal show, upon careful inspection, that the coal is in thin layers, and that each of these layers was formed from the bark of a tree, and from nothing else. These trees are more often the Sigillaria, but sometimes we find the bark of a Lepidodendron changed to coal. A specimen of such bark is shown in Fig. 287. The film of coal is about one twentieth of an inch thick. In the case of Sigillaria the coal is sometimes much thicker.

While much of the coal was formed in this manner, there is little doubt that all the various forms of the buried vegetation contributed to it. In the higher seams of coal, in the Alleghany coal-field, the Sigillariæ are so few, and the Lepidodendra so very rare, if found at all, that it is difficult to believe that they could have entered largely into the mass of the coal.

Many have supposed that in the coal period the atmosphere contained an unusual quantity of carbonic acid, which was absorbed by the growing vegetation, and stored away

in the coal seams. The large number of air-breathing Amphibians, with which the coal marshes sometimes swarmed —17 genera and 34 species having already been found in one marsh in Ohio—makes the existence of an excess of noxious carbonic acid in the air extremely doubtful. The atmospheric circulation was doubtless the same then as now, and the carbonic acid would have been equally distributed over the earth. The extent of the coal marshes, compared with the whole surface area of the earth, was insignificant.

Fig. 287.

Bark of a Lepidodendron changed to Coal.

152. Kinds of Coal. There are two varieties, *bituminous* and *anthracite*. The latter is, however, only a changed form of the former, which through heat has lost its bitumen. If we put ordinary bituminous coal into a retort at the gas works, and apply heat, the coal is changed to coke, with a loss of its gases. In much the same way the coal in the anthracite regions, which was at first bituminous, was heated while still under the great pressure of the overlying rocks; the bitumen, in the form of gases, was slowly driven away, and thus the mass was changed into a solid compact coke, or anthracite coal. It is simply a metamorphic form of coal, as marble is a metamorphic

limestone. Such anthracite coal is found in several long, narrow basins in north-eastern Pennsylvania.

In the Blossburg and Broad Top Mountain coal-fields, in Pennsylvania, which lie midway between the anthracite to the east and the bituminous coals to the west, the coal is *semi-bituminous*, having lost only a part of its gases. The same is true of the coal in the Cumberland coal-field in western Maryland.

In the Interior States there is no anthracite coal, no portion of our coal-fields having ever been subjected to much subterranean heat.

153. **The bituminous coals** of the Interior may be classed as *Caking*, *Splint*, and *Cannel*.

(1) *Caking Coal* melts more or less in the fire, and forms a cake or crust, which needs to be broken to give the fire a good draft. The best coke is made from this variety. Caking coals are generally bright and somewhat resinous in appearance, and break into cubical blocks. The Pittsburgh coal is an excellent illustration of a caking and coking coal. The Connellsville coke, which is used in most of the Interior States, is made from coal of the Pittsburgh seam.

(2) *Splint Coal* is more laminated, and splits into firm layers. When broken, the edges of these layers show a ragged, splintery fracture, quite unlike the fracture of caking coal. It does not soften and melt in the fire like the latter, and hence is called free or dry-burning. This property renders it available for the blast furnace in the raw or uncoked state, because it does not choke the draft as caking coal would do if used in the same manner. The splint coal is so used in several Interior States. Sometimes splint coal comes from the mines in large blocks, and is consequently called *block coal.* This term is given to the splint coal of Brazil, Indiana, and of the Mahoning Valley,

Ohio. Splint coal is found in West Virginia, Ohio, Kentucky, Indiana, and doubtless in other Interior States.

(3) *Cannel Coal* is a hard variety, generally of a dull color, and has its fracture in curves, like the curves of many shells, and hence called a conchoidal fracture, from *concha*, a shell. It makes a brighter flame than any other coal, and is therefore a popular coal for the parlor fire. It is also used more or less in gas works. Cannel coal was probably formed from vegetable mud, like the muck in modern swamps. It is sometimes quite pure, but more often contains an excess of ash, which is nothing more than the clayey part in the ancient muck. In the coal swamps such vegetable muck beds would be found only here and there; and hence we find cannel coals in local basins, while all around them the coal of the same seam is the usual caking or splint variety.

Cannel coal is found in most of the coal-fields of the Interior States, but it is most abundant in West Virginia. No cannel coal has been found in the anthracite fields of Pennsylvania. It probably existed, but lost its identity when changed to anthracite.

The name cannel is derived from candle, the coal having been used as a substitute for candles, and hence called candle coal, which became corrupted into cannel coal.

154. Investigation of Coals.—It is often necessary to know the quality of the coals we use. If we wish to use a coal in smelting iron ores, in a blast furnace, we must guard against sulphur, for this injures the iron. If, however, the sulphur chiefly passes off with the gases, in the top of the furnace, it will do less harm than if it remains in the coke. If we desire a coal for making gas, we also reject one with too much sulphur in it, since whatever sulphur enters the gas must be removed by some purifying process before the

gas is fit to be used. We need, furthermore, to know whether the gas produced has a high illuminating quality, for there is great difference in the light power of gases made from different coals. Cannel coal gas gives the brightest light.

Again we need to know whether a coal has a large or a small amount of ash. All coal must have some ash, for the vegetation forming it possessed earthy elements. Sometimes a coal will show less ash than we have reason to believe the old coal trees and plants contained. This is easily explained. The first trees which grew in the coal marsh were rooted in the clayey soil, and drew from the ground the needed earthy elements. After a time, as the falling vegetation accumulated in the marsh, the trees and plants would root themselves in this increasing vegetable mass and not in the clay below, and would of course derive their earthy matter, or ash, from the mass. In this way the same earthy matter, or ash, would do duty over and over again, and the coal thus formed would have less ash than if all the vegetation forming it had been rooted in mud or regular soil, and not in the vegetable ooze. This may be illustrated by Fig. 288, where the trees on the left are rooted in the under clay, and those on the right are growing in the vegetable mass above. It is seldom that a coal contains less than one per cent of ash, while from three to five per cent is more common; but very good coals, in other respects, sometimes contain more.

Fig. 288.

155. There are two ways of analyzing coals. One is an *ultimate* analysis, by which the exact per cent of carbon,

hydrogen, oxygen, nitrogen, water, sulphur, and ash are determined. From these the full heating power of the coal may be computed. The other is a *partial* or *proximate* analysis, by which the per cent of water, volatile combustible matter (gases), fixed carbon, sulphur, and ash are determined. The fixed carbon is so much of the carbon of the coal as remains after the volatile gases are driven off by heat. This method of analysis is less complete than the other, but it serves a valuable purpose.

A sample of each kind of analysis is given below—each made of the same lump of coal, and by the same chemist, Prof. T. G. Wormley.

Ultimate Analysis.		*Proximate Analysis.*	
	Per Cent.		*Per Cent.*
Carbon, ...	78.99	Moisture, ...	2.47
Hydrogen, . . .	5.92	Volatile Combustible, .	31.83
Nitrogen, . . .	1.58	Fixed Carbon, . .	64.25
Oxygen, . . .	11.50	Ash, ...	1.45
Sulphur, . . .	0.56		100.00
Ash, ...	1.45	Sulphur included above,	0.56
	100.00	Sulph. remaining in Coke,	0.84
Water included above,	2.47		

Specific gravity, 1.260

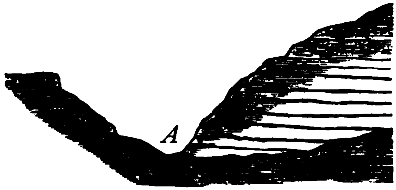
156. The rocks of the Coal-measures often rest upon an uneven floor. It is not uncommon to find in Ohio the lower coal rocks filling old valleys in the Waverly sandstone. This is shown in Fig. 289.

The existing valley, *A*, is bordered on one side by Waverly rocks, and on the other by the Coal-measures, in which are several seams of coal. The ancient valley extended to the right under the rocks of the Coal-measures.

These ancient valleys, in the Waverly, were probably eroded by the action of streams, there being proof that for a long period of time the Waverly rocks of Ohio were elevated above the ocean before the formation of the Coal-measures began.

157. In West Virginia, in the valley of the Kanawha River, the Coal-measures are more than 2,000 feet thicker than in Ohio. This is shown by taking the Pittsburgh seam of coal, which extends through both states, as a datum line or base to measure from. From this seam of coal we descend, in the Ohio series, 700 to 800 feet to the Waverly, while, in West Virginia, we descend a little more than 3,000 feet to the Lower Carboniferous rocks on the eastern margin of the coal-field. This shows that the Coal-measures are much thicker in West Virginia, and that they were formed in a great basin or trough.

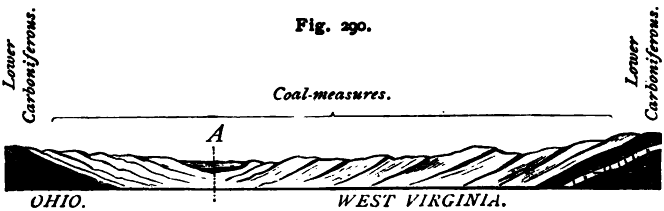
Fig. 289.



Ancient Valley in the Waverly.

Fig. 290 is a section across the whole coal-field, from the Ohio side to the mountains of West Virginia. *A* marks the position of the Pittsburgh seam of coal. It will be seen at a glance that the Coal-measures are much thicker on the eastern side of the Pittsburgh coal seam than on the western.

Fig. 290.



Section of Alleghany Coal-field across Ohio and West Virginia.

It must be remembered that the rocks were originally horizontal, and that the seams of coal were formed from vegetable matter accumulated in broad horizontal marshes. Hence, the appearance of the coal-field, when first formed, must have been something as represented in Fig. 291.

Fig. 291.

It was not until after the Coal-measures were deposited that the Alleghany Mountains were lifted up, and the coal-field was thrown into the synclinal form or basin shown in Fig. 290.

158. In West Virginia, a few miles east of Parkersburg, is an uplift which has brought the lower rocks of the Coal-measures to the surface. It is called the oil uplift, or "oil break," and extends from south of the Little Kanawha River, at Burning Springs, in a northern direction, crossing the Ohio River a few miles above Marietta. The rocks, at some points along the uplift, must have been elevated from 800 to 1,000 feet, forming a long narrow ridge, the top of which is now planed off. The section, shown in Fig. 292,

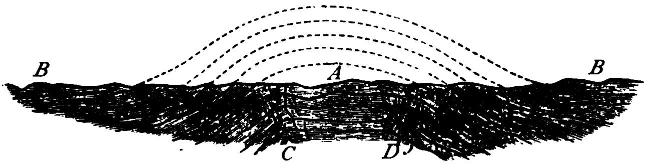


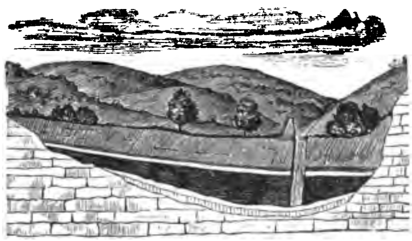
Fig. 292.

represents the uplift. The dotted lines indicate the position of the strata now removed. *B B* are horizontal strata of the upper Coal-measures. At *A* we have the lower rocks

of the series. At *C* and *D* are fissures in the rocks, caused by the bending and cracking of the strata. These fissures contain petroleum, and are easily reached by boring. The deepest fissures contain light oil, but those nearer the surface, or such as are connected with the surface, now contain a heavy, thick oil, the more volatile portion having escaped. The heavy oil is valued for lubricating purposes.

159. Coal is sometimes found in places where we should little expect to find it. For example, in Lincoln County, Missouri, there are several localities, of quite limited extent, where very thick seams of coal have been found. Geological investigations by Mr. Potter showed that the coal lay in small basins, eroded in the Encrinital or Burlington limestone. One of these coal-basins is shown in Fig. 293. The coal at its thickest place is fourteen and a half feet thick. In the shale over it are plants of the true Coal-measures. Of course the coal is not of the age of the Burlington limestone any more than the coal found near Richmond, Virginia, which rests upon granite, is as old as the granite. After the Burlington limestone had been formed in the sea bottom, it was lifted up and became dry land, subject to erosion and waste. In the coal time, there was a marsh in one of the little hollows or valleys in the rock, and from the accumulated vegetation a thick seam of coal was formed.

Fig. 293.



Coal in Small Basins, in Burlington Limestone, Lincoln County, Missouri.

160. Iron Ores in Coal-measures. — In several of the Interior States iron ores are found interstratified with

the other rocks. In Ohio, Kentucky, West Virginia, and Indiana, these ores are used in furnaces. They were all originally carbonates of iron, but in many cases they have been weathered and changed to brown hematites, in which form they are preferred.

In southern Ohio and north-eastern Kentucky is a well-known layer of ore, called the "limestone ore," because it rests upon a well defined fossiliferous limestone, as shown in Fig. 294. It is generally a limonite (hydrated sesquioxide of iron), and makes an excellent quality of iron.

Fig. 294.

Sometimes iron ore is in balls or nodules, embedded in shales and clays, as shown in Fig. 295. The iron was originally disseminated through the mass of mud, now changed to shale. By the action of chemical affinity, the particles of iron were brought together and formed balls, often flattened plates or discs, and sometimes regular layers. It is curious to observe that sometimes these balls, although formed in clay shales, contain no clay whatever, so complete has been the separation. On the other hand, we find in the Coal-measures clay shales containing considerable iron in its original state of dissemination through the whole mass, the action of chemical affinity never having taken place. These are the dark red and chocolate-colored shales frequently seen in the upper Coal-measures of Ohio. They often contain numerous coal plants, but these, in their decay, have not had the effect upon the ore sometimes attributed to organic matter. In the lower Coal-measures

Fig. 295.

of Ohio the shales are often white, the iron having been entirely removed to form the layers of ore. Over seams of coal we sometimes find bituminous shales with considerable iron ore disseminated through them. Such shales constitute *black-band* ores. The ore is chiefly a carbonate, but generally a small part of it is a sesquioxide. Fig. 296 shows a seam of black-band over a seam of coal.

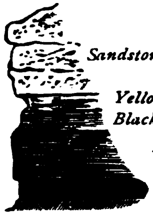


Fig. 296.

We sometimes see the shale forming a black-band ore in one place, and, not far away, the ore gathered out of the same shale into balls—generally in rows, as shown in the section, Fig. 295.

Black-band ores are found in several of the Interior States, but they have been more extensively wrought in Ohio than elsewhere. In Scotland they have been the basis of extensive and profitable iron industries.

161. In some of the Interior States we find iron ores, suitable furnace coals, and limestone for flux in the same hills,—a union in one spot of all the elements needed in the manufacture of iron. But it must be conceded that coals and ores of the best quality are far less abundant than those of inferior grades.

The aggregate area of coal-fields in the Interior is very large, as the geological map shows. While some of this area contains very little valuable coal, there are other large districts in which there are several distinct seams of coal, and the supply is practically inexhaustible. Without doubt very much coal has been removed by the erosion of portions of the coal-fields.

Broad valleys have been worn out, and the coal seams which once stretched across the intervals are now gone.

Let one stand upon one of the high hills of West Virginia or south-eastern Ohio, and look down into the deep valleys around him, and he will have some conception of the enormous waste of coal since the work of valley-making began. Frost and rain and streams have been busy at work, during long geological ages, in wasting away our Coal-measures. It should be remembered that, with the exception of some limited areas, the Interior coal-fields have been above the ocean, and, as a part of the continental surface, subject to erosion and waste, from the time of the first emergence at the end of the coal period, down to the time of the drift epoch, when for a time there was a submergence. During this immense period of time probably more coal has been removed than Great Britain ever possessed. But the loss is well made up by the beautiful and fertile valleys which intersect our coal-fields.

CHAPTER XIV.

COAL-MEASURES — CONTINUED. PERMIAN.

162. Plants of the Coal Period.—The leading land plants of this time were *Ferns*, *Lycopods*, and *Equiseta*.

The ferns sometimes grew into large trees, as they do now in some parts of the world. The Lycopods were allied to the small ground or trailing pine of the present time, of which Fig. 297 represents a common form, the "club-moss" (*Lycopodium lucidulum*). No modern Lycopods are more than four or five feet high, but those of the coal period were often large trees. The Equiseta were allied to the modern horse-tails, or scouring rushes, but grew to be very large. Trunks of Conifers are found buried in the sandstones and shales of the Coal-measures, where they were evidently drifted. It is doubtful whether they grew in the coal swamps in such numbers as to contribute largely to the

Fig. 297.

Lycopodium lucidulum.

beds of coal. They probably grew abundantly on the high lands bordering the marshes.

163. Lycopods. — (1) One of the most common forms of plant is the *Stigmaria*, so named from *stigma*, a dot. It is quite abundant in some sand-rocks, and in the clays immediately below the seams of coal. It is also sometimes found in great numbers in the coal itself. Fig. 298 represents a portion of a Stigmaria found in a block of coal, with the small flattened rootlets attached. The round scars are the sockets from which other rootlets were broken off. Under-clays are often filled with these rootlets, while the body of the Stigmaria is more rare. Fig. 299 represents the end of a Stigmaria, somewhat out of shape, but showing terminal scars. Some, with apparently good reason, regard the Stigmaria as a deep-floating plant, which, when favorably imbedded in the ooze of a marsh, sent up a fruiting stem, which grew to be a Sigillaria tree. Others regard it as the proper root of the Sigillaria, and, perhaps, of other Lycopods.

Fig. 298.

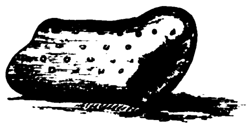


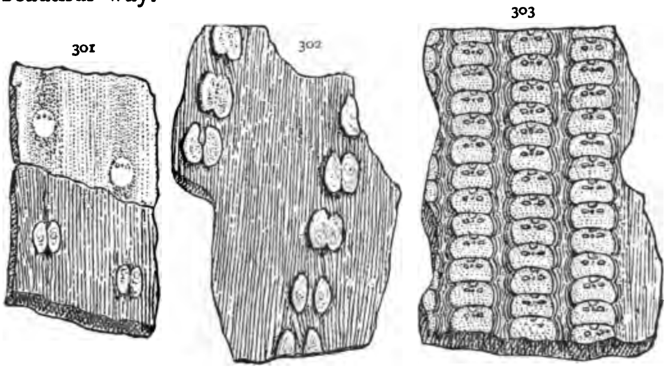
Fig. 299.

Fig. 300.

Sigillaria Brardii.

(2) The *Sigillaria*, or seal-tree, from the resemblance of the leaf-scars on its trunk to a seal (see Fig. 300), grew to great height and size in the coal marshes. Hundreds of the flattened trunks of this tree are found

in the roof shales in coal mines, and very frequently in the coal itself. The leaves were long and slender, and around their bases the bark was wrinkled in a very curious and beautiful way.



Figs. 301-303.

Fig. 301, Sigillaria reniformis; 302, Sigillaria reniformis, inner scars; 303, Sigillaria tesselata (?).

Fig. 301 is a somewhat common form, called *Sigillaria reniformis* (kidney-shaped). The faint scars above, with the dots showing the points of attachment of the leaves, belong to the outer surface of the bark, while the twin scars below, show the changed form of the same scars under the bark and next to the wood.

Fig. 302 is probably another form of the last species, representing the inner scars, arranged somewhat spirally around the tree.

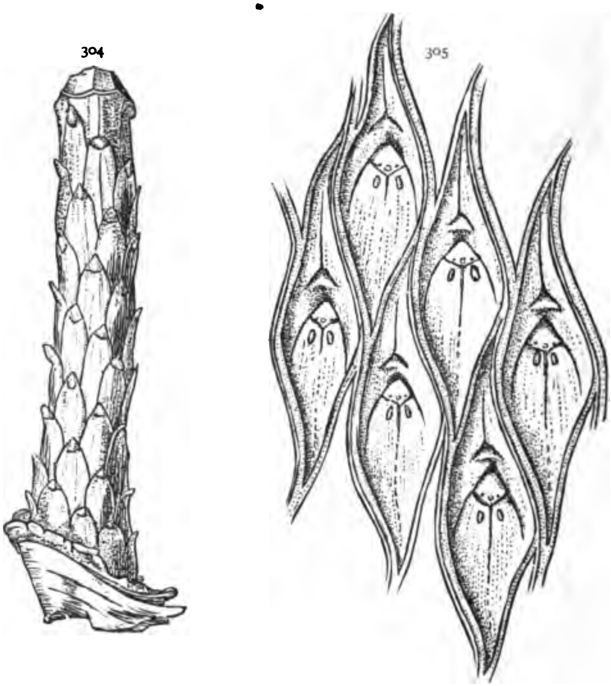
Fig. 303 represents a portion of the bark of a *Sigillaria tesselata* (?), from the shale of the Nelsonville, Ohio, seam of coal. It is very beautiful as seen upon the stone.

(3) *Lepidodendron.*—Another form of the ancient Lycopods is the Lepidodendron, or scaly tree. It was a large and tall tree, and bristled with long slender leaves, something

like those of the pine. Some leaves are a foot long. The different species of this tree are determined by the markings of the bark around the bases of the leaves. Such markings often excite wonder for their symmetry and beauty. But figures as regular and almost as beautiful are often seen on the branches of the modern coniferous trees. For example, Fig. 304 is an exact copy of a branch of a common pine, which served the author for a Christmas tree.

304

305



Figs. 304, 305.

In Fig. 305 is shown a most beautiful Lepidodendron, two thirds natural size, allied to the *Lepidodendron aculeatum*, from the shale over the Nelsonville seam of coal in Ohio.

No artist could devise a more perfect combination of graceful curves. The long, slender leaves were attached in the middle of the scars, where we see three dots.

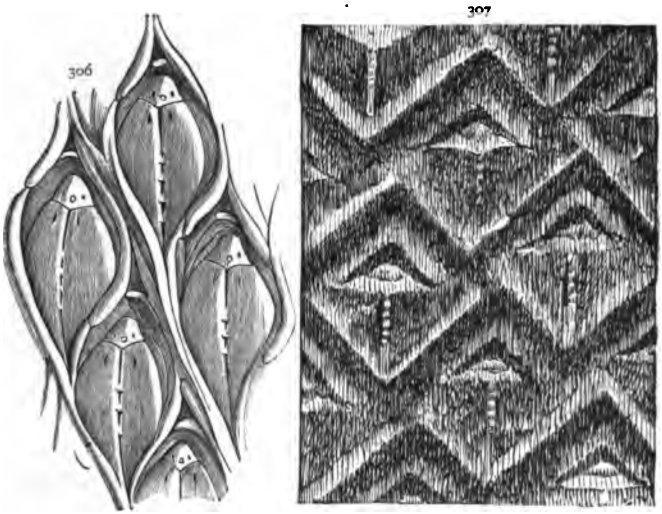


Fig. 306, 307.

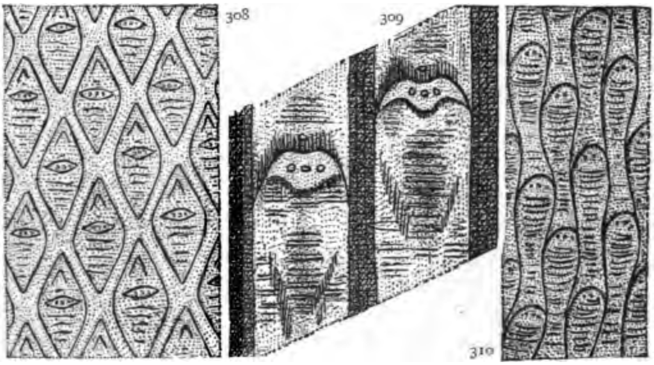
Fig. 306, Lepidodendron Sternbergii, natural size.
Fig. 307, Lepidodendron Lesquereuxii, natural size.

The *Lepidodendron Sternbergii* (Fig. 306) is a somewhat common form, and one of no little beauty.

In Fig. 307 we see how curiously Nature has changed her pattern, for there is not a single curved line—"the line of beauty." The pits where the leaves were attached are triangular, and the surrounding wrinkles of the bark are in squares. This specimen was found in Ohio, near the base of the Coal-measures.

It is a new and rare species, which has been named after Mr. Lesquereux, so distinguished for his labors in palæontological botany.

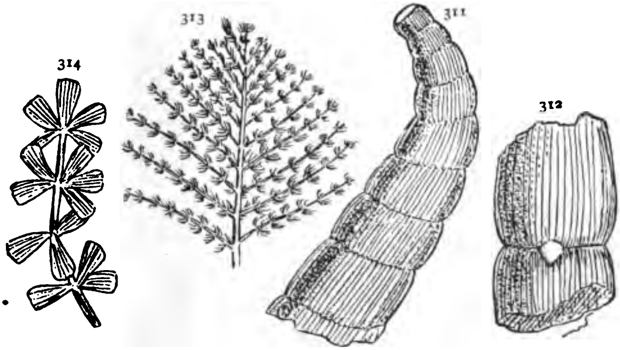
The species represented in Figs. 308–310 were found in Illinois, and are described by Mr. Lesquereux, in the Geological Report of that state.



Figs. 308-310.

Fig. 308, Lepidodendron deplotegioides; 309, Lepidodendron costatum; 310, Lepidodendron Wortheni.

164. **Equiseta.**—This is a comprehensive group, taking its name from the modern Equisetum, or horse-tail. One of the most common of the fossil forms is the Calamite (κάλαμος, a reed). The stems were fluted, hollow, and jointed, with leaves in whorls growing from the joints. In the roof shales, over seams of coal, they are often very numerous, generally flattened by pressure. The author has found such flattened stems from eight to ten inches wide. Fig. 311 represents a common form, the *Calamites cannæformis.* Calamites are often found in the sand-rocks of the Coal-measures, standing erect and not flattened. Fig. 312 shows another form, with the scar where a branchlet was broken off. In Fig. 313 we have a very beautiful plant of this group, called *Asterophyllites equisetiformis.* It is not very uncommon. A more common plant is the *Sphenophyllum Schlotheimii*, Fig. 314. In Fig. 316, we have a form of plant



Figs. 311-314.

Fig. 311, Calamites cannæformis, one ninth natural size; 312, Calamites, with scar of branchlet; 313, Asterophyllites equisetiformis, one tenth natural size; 314, Sphenophyllum Schlotheimii.

quite abundant in some places in Ohio, in the shale over the Pittsburgh seam of coal. It has a slender jointed stem, with long leaves growing from the joints.

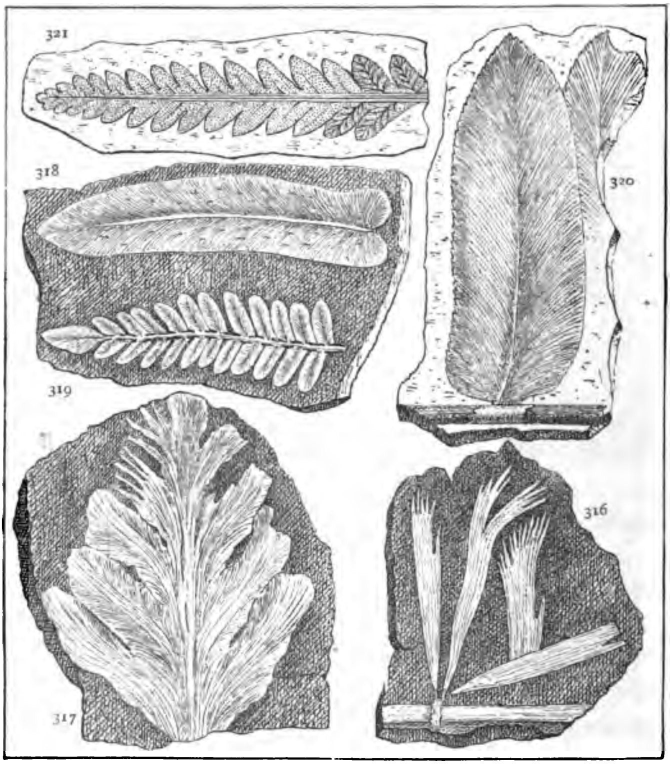
Fig. 315.

Alethopteris lonchitica.

In Fig. 328 we have another Equisetaceous plant, *Asterophyllites erectifolius*, from the lower Coal-measures of Ohio.

165. Ferns.—Plants of this group were very abundant in the swamps of the coal period, and their fronds and leaflets are often very beautifully preserved.

In Fig. 315 we have the *Alethopteris lonchitica*, a very pretty fern, common to this country and to Europe. The nervation of the leaves is often preserved in great distinctness.



Figs. 316-321.

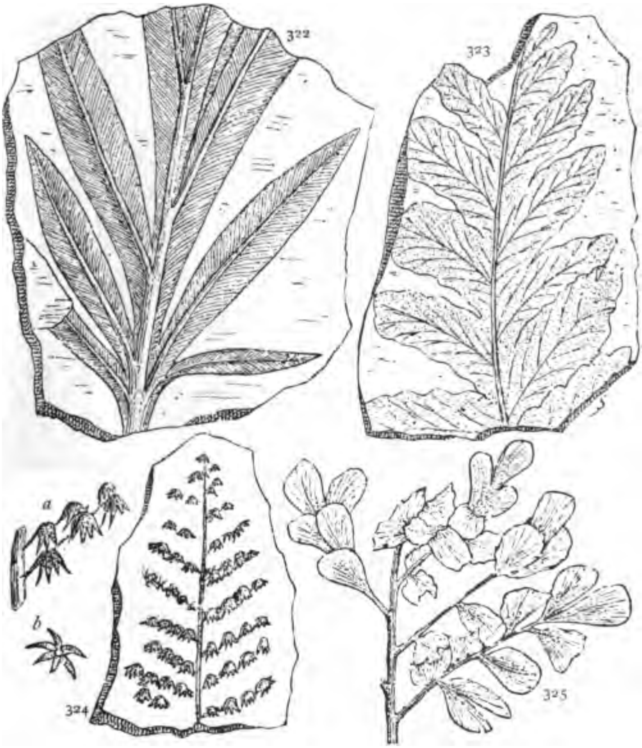
Fig. 316, Plant of the Equiseta family, reduced, new species.
Ferns—Fig. 317, Rhacophyllum lactuca reduced; 318, Neuropteris hirsuta; 319, Neuropteris flexuosa; 320, Neuropteris verbenæfolia; 321, Alethopteris Mazoniana.

All the plants in the above group are ferns, except Fig. 316, which belongs to the family of the Equiseta.

Fig. 317 is a broad-leafed fern, probably low growing. In Figs. 318 and 319 we have two of our most common species. The *Neuropteris hirsuta* is named from the little

vegetable hairs which grew upon the surface of the leaf. The species represented by Figs. 320, 321, 322, and 324 are found in Illinois.

Fig. 325 shows an interesting plant, reduced one half, found by Prof. Fontaine in West Virginia.



Figs. 322 - 325.

Fig. 322, Megalopteris Southwelli, near base of Coal-measures in Illinois, reduced one half; 323, Alethopteris hymenophylloides, Illinois; 324, Staphylopteris asteroides, Illinois, the fruiting stalk of a fern; 324 *a* and *b* are the same, enlarged; 325, Archæopteris —— ? lower Coal-measures, West Virginia, reduced one half.

Figs. 326-328.

Fig. 326, Megalopteris Harttii, the top of a large fern; 327, Eremopteris marginata; 328, Asterophyllites erectifolius.

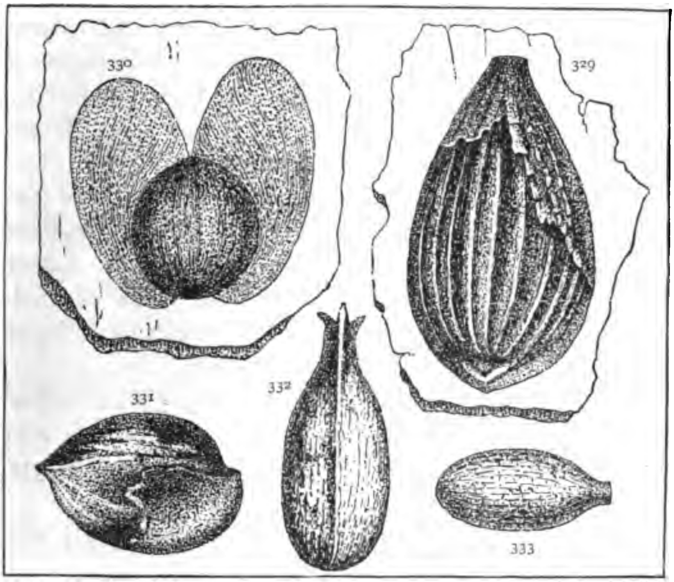
All the above were from the base of the Coal-measures in Ohio. They are reduced one half.

77, **166. Fruit.**—Many nuts and seeds are found among the plants of the Coal-measures. Some of them are figured on the opposite page. As they are seldom found attached to any trees, but separated and scattered, it is not certainly known to what trees they belong.

Attached to the stems of Cordaites, a tree supposed to be allied to the Conifers, are sometimes found clusters of flowers, and on other stems are nutlets, allied to some of the

simpler forms of Cardiocarpon; but with this exception no fruits have been found attached to any of the coal plants.

Figs. 329-333.

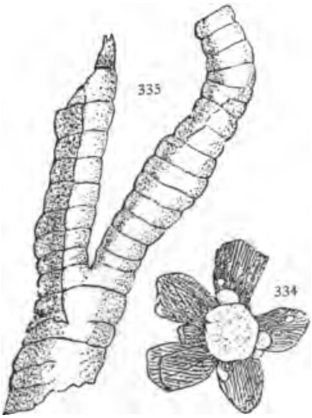


Nuts of the Coal-measures.

Fig. 329, Rhabdocarpus carinatus, showing a portion of the covering; 330, Cardiocarpon samaræforme, showing the wings; 331, Trigonocarpon, showing a part of the covering; 332, Trigonocarpon tricuspidatum, in its covering; 333, Trigonocarpon tricuspidatum, the nut without the covering.

The foregoing plants from the Coal-measures are only a very small part of the whole number already found and described. Doubtless many new plants will hereafter be discovered. No recreation can be more attractive to students than to explore the shales over the coal-seams in search of plants.

167. Marine Plants in the Coal-measures are not very common, but the author has found fine specimens of the Spirophyton (see Fig. ~~331~~ 234). A marine plant, *Asterophycus Coxii*, from the Coal-measures of Indiana, is shown in Fig. 334. It is figured one fourth the natural size.



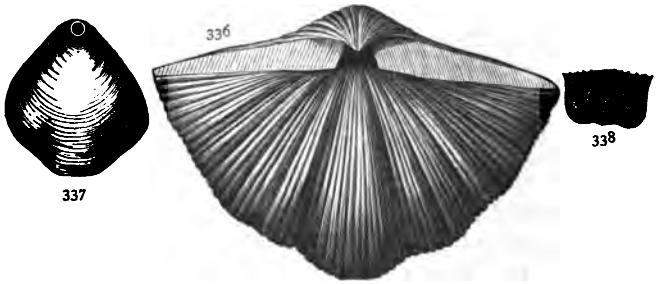
Figs. 334, 335.

In Fig. 335 we have the *Palæophycus Milleri*, another marine plant from the Lower Carboniferous rocks of Indiana. It resembles forms found in older rocks.

168. Mollusks.—*Spirifer cameratus* (Fig. 336) is one of the most common shells in the Coal-measures, as are also *Athyris subtilita* and *Chonetes mesoloba*, shown in Figs. 337 and 338.

These, as well as the Producti (Figs. 340–343), and

Figs. 336–338.

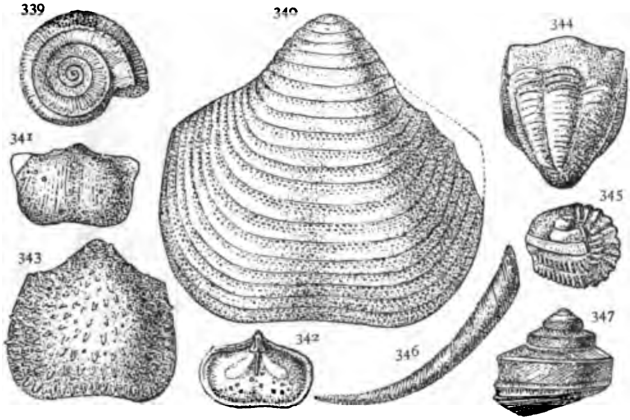


337

Animal Fossils of the Coal-measures.

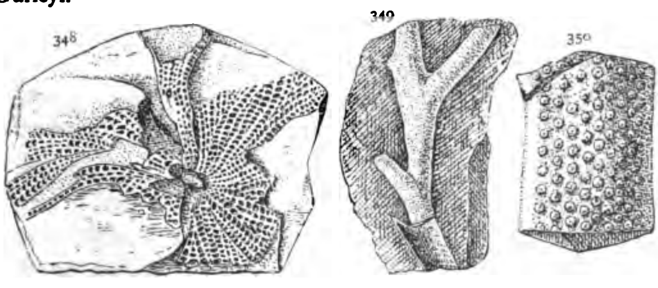
Fig. 336, Spirifer cameratus; 337, Athyris subtilita; 338, Chonetes mesoloba.

Fig. 359 on page 184, all belong to the Brachiopods. The Gasteropods are shown in Figs. 339, 346, and 347. The Phillipsia (Figs. 344, 345) is the last of the great family of Trilobites, all the larger forms having died out.



Figs. 339-347.

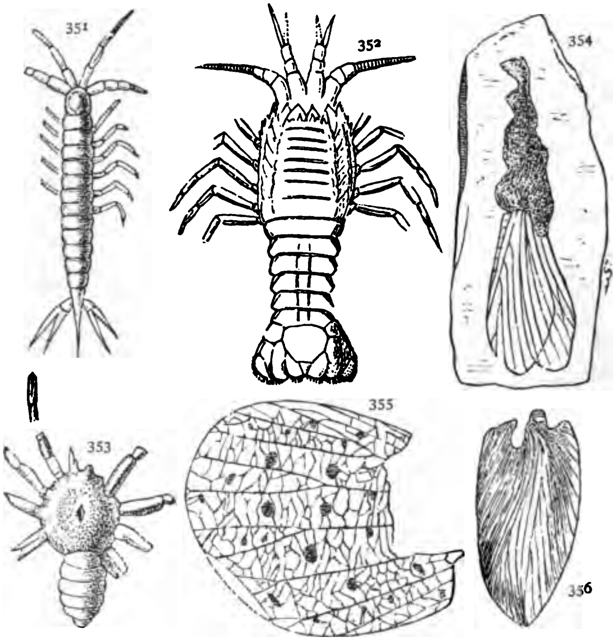
Fig. 339, Euomphalus subrugosus; 340, Productus punctatus; 341, Productus longispinus; 342, same, inner side of valve; 343, Productus Nebrascensis; 344, Phillipsia Sangamonensis; 345, Phillipsia scitula; 346, Dentalium Meekianum; 347, Pleurotomaria Gurleyi.



Figs. 348-350.

Fig. 348, Synocladia biserialis; 349, Ptylodictya carbonaria; 350, same, enlarged.

The preceding forms (Figs. 348 and 349) belong to the Polyzoa, and are grouped in that division of the Mollusca. They are to be distinguished from the coral-making Polyps, which are Radiates.



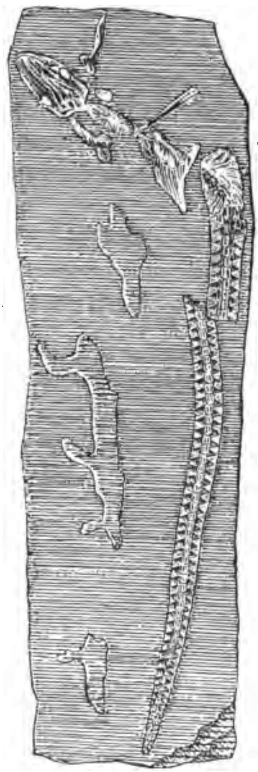
Figs. 351-356.

Fig. 351, Acanthotelson Stimpsoni; 352, Anthrapalæmon gracilis; 353, Arthrolycosa antiquus; 354, Miamia Danæ; 355, Megathentomum pustulatum; 356, Mylacris anthracophila.

169. **Crustaceans.**—Figs. 351 and 352 resemble forms of the Crustacea now living. While the Trilobites are dying out, new Crustaceans are appearing, allied to the shrimps, craw-fish, etc. In Fig. 366, page 185, is another Crustacean, from the Carboniferous rocks of Illinois, the pioneer of the modern Limuloids (king crabs).

The introduction of so many insects in the period of the Coal-measures is another fact of the highest interest. Insects would naturally belong to the marshes and wooded uplands of that day. Already about thirty species have been described from the Coal-measures of America. The wings of three kinds are seen in Figs. 354–356, all from Illinois. Fig. 353 represents one of the many spiders in whose webs the smaller insects were doubtless caught. It was then as now, the strong and the cunning preyed upon the weak and the unwary.

Fig. 357.



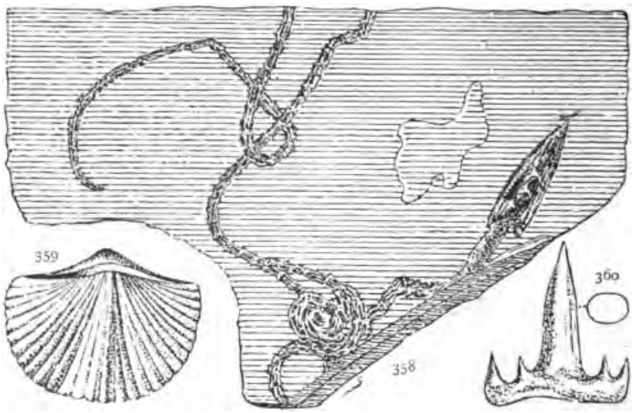
Ptyonius serrula.

170. Vertebrates. — Of the many animals of the Coal-measures none are more interesting than the vertebrates.

No reptiles have been found in the Devonian rocks, but we soon after begin to obtain hints of them in the tracks left in the mud in the days of the Lower Carboniferous. These footprints resembled those of the Labyrinthodonts, which afterwards were abundant. These Labyrinthodonts were Amphibians, breathing like the frog, first by gills in the water, and afterwards by lungs; they were so named from the intricate and labyrinthine structure of their teeth. Some of them may have retained the gills through life, in which case they would have had the use of both gills and lungs as occasion required.

Underlying the "Big vein" of coal at Linton, near the mouth of Yellow Creek, Ohio, is a layer of impure cannel shale, from which have been obtained thirty-four species of air-breathing Batrachians, belonging to seventeen genera. In the same layer are found fishes innumerable.

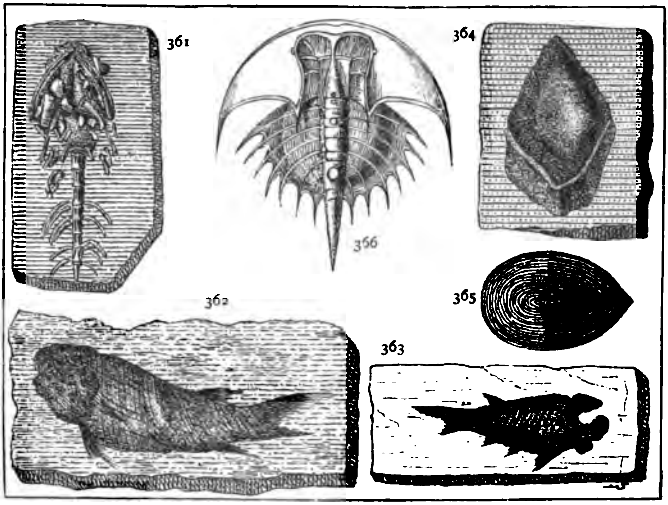
Fig. 357 represents a *Ptyonius serrula*, one half natural size. It had a narrow head, and a long, flexible body like that of a snake. Other genera had broad, flat heads. They were generally armed with strong teeth, and their heads were covered with thick bony plates. They appear to be a connecting link between the strong, heavy-armored fishes of the Devonian and the Saurian reptiles which appeared in formations succeeding the Coal-measures.



Figs. 358-360.

Fig. 358, Phlegethontia linearis, ⅔ natural size; 359, Spirifer opimus, ⅔ natural size; 360, Cladodus acuminatus.

In Fig. 358 we have a curious form, the *Phlegethontia linearis*, two thirds natural size. Its head is sharply pointed, and its body, a foot long, is tangled like a string.



Figs. 361-366.

Fig. 361, Cocytinus gyrinoides; 362, Eurylepis granulatus; 363, Eurylepis minimus; 364, Scale of Megalichthys; 365, Scale of Cœlacanthus elegans; 366, Euproöps Danæ.

Of the above, Fig. 361 is a Batrachian from Linton, Ohio, as were the fishes shown in Figs. 362 and 363. Figs. 364 and 365 represent scales of fishes, and Fig. 360, on page 184, a tooth of a fish.

The *Eurylepis minimus* is of natural size. Small as it was, this and the other fishes in the ancient Linton Pond doubtless afforded food to the Batrachians which lived there with them. The food could not have been very nutritious, since these fishes were Ganoids, and were covered with hard, thick, enameled scales, firmly interlocked by a sort of tongue and groove arrangement. These scales constitute the chief part of the Coprolites found in the shales.

The *Euproöps Danæ*, Fig. 366, is a crustacean, not unlike the modern horse-shoe crab.

171. **Permian.**—The Permian Period follows that of the Coal-measures. There has been much question relative to the existence of Permian rocks in the Interior States. A few fossils, chiefly shells, of Permian type were found several years since in Kansas and Nebraska, associated with those of the Coal-measures. The rocks containing these Permian fossils are by many thought to be of true Permian age, and are generally so designated on the geological maps. But until recently it has been doubted whether in States east of those mentioned any Permian rocks existed.

In Vermilion County, Illinois, in some shales, at the summit of the Coal-measures, have been lately found the bones of vertebrates, which Prof. Cope regards as the bones of Saurians of Permian types, but with these are fishes and mollusks common to the Coal-measures. No true Saurians have ever before been found in the Coal-measures, and Prof. Cope concludes that the bone-bearing shales of Vermilion County truly represent the Permian Period.

CHAPTER XV.

MESOZOIC TIME, OR AGE OF REPTILES.

THE Mesozoic Time is divided into three Periods—the *Triassic*, *Jurassic*, and *Cretaceous*.

172. **The Triassic** is the earliest Period, and follows the Permian of the Palæozoic Time. The term Triassic refers to a triple subdivision of the formation in Germany.

While no Triassic rocks have been found in the Interior States, rocks attributed by Prof. Dana to this age are common in the Atlantic States. They appear in the Connecticut Valley, and in a belt stretching from the Palisades on the Hudson to Richmond, Virginia, and also in the Deep River region in North Carolina. There are also large areas in the Rocky Mountains, which are supposed to be Triassic in age.

A peculiar feature of the Triassic areas of the Atlantic border is the ridges and hills of trap which have been thrust up in a fluid state through fissures in the Triassic strata. Mt. Tom and Mt. Holyoke in Massachusetts, Talcott Mountain west of Hartford, the Meriden Hills, East and West Rocks at New Haven in Connecticut, and the Palisades along the Hudson are some of these trap hills and ridges. The rock cuts and tunnels on the railroads at Jersey City, opposite New York, are excavated in one of these trap hills.

The Triassic rocks are chiefly sand-rocks and shales. The sandstone is very largely quarried in Connecticut and New Jersey, and used as a building-stone in New York and other eastern cities.

173. **Fossils** in this formation are extremely rare, but nevertheless an extremely interesting group of animals is known to have lived in the Connecticut Valley at the time the sandstones and shales were in progress of accumulation. These animals wandered along the shores, doubtless in search of food, and their foot-prints have remained in the mud now hardened into rock.

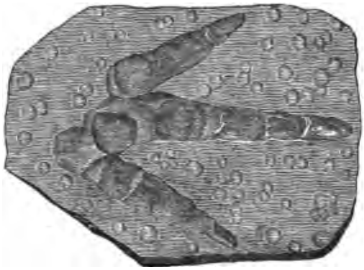


Fig. 367.

These were first designated as bird tracks; but most of them, if not all, are now considered to be the tracks of air-breathing reptiles, although it is highly probable that birds existed at that time.

Fig. 368.

Tracks of Otozoum Moodii.

The late President Hitchcock described one hundred different kinds of these tracks. Some are more than twenty inches long, and must have been made by a huge animal. On the other hand, some are very small. They are often very numerous, and many are found on the same slab.

Fig. 367 shows one of the more bird-like tracks, and also

indentations made by rain drops. Much is yet to be learned in regard to these animals. Only a very few fragmentary bones have been found in the rocks containing foot-prints.

Fig. 368 represents the tracks of a huge Amphibian — the order to which toads belong. In the rock these tracks are 20 inches long by 15 inches wide.

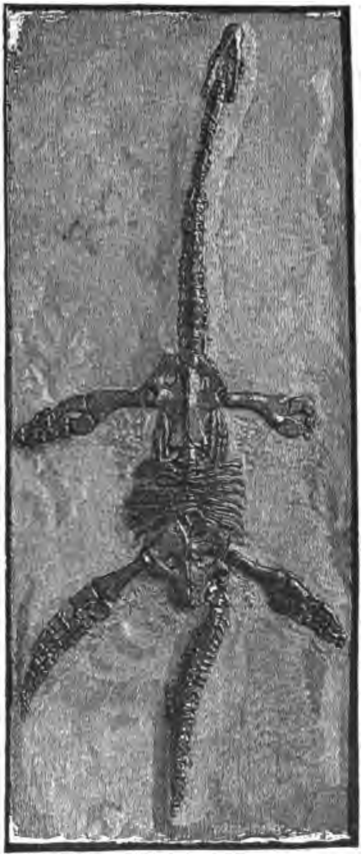


Fig. 369.

In the Triassic rocks of North Carolina, Prof. Emmons found the jaws of a small mammal, belonging to the class of Marsupials, the class to which the modern opossum belongs. This is the oldest marsupial yet discovered, and introduces the great class of Mammalia.

Valuable seams of bituminous coal, of good quality, exist in the Triassic rocks near Richmond, Virginia, and also in North Carolina.

Several plants have been found in these rocks: as *conifers* in the Connecticut Valley, in New Jersey, and Pennsylvania; *cycads*, in North Carolina and Pennsylvania; and *ferns*, in the Richmond coal-field, and at other points.

79.

174. Jurassic Period.—This Period derives its name from the Jura Mountains of Europe.

No rocks of this Period are found in the Interior States, unless it may be the Gypsum beds of Fort Dodge, Iowa, to be noticed hereafter. The only well ascertained deposits of this Period are in the far West—in the Black Hills, in the eastern ranges of the Rocky Mountains, in the Sierra Nevada, and on the Pacific slope.

The Jurassic rocks in Europe are extremely rich in fossils, but comparatively few have been found in this country. The vertebrates in the foreign beds include birds, fishes, flying lizards, or saurians, etc. There were also insects, crustaceans, crinoids, star-fishes and mollusks.

Fig. 369 represents a saurian, from fifteen to twenty feet long, called the *Plesiosaurus*.

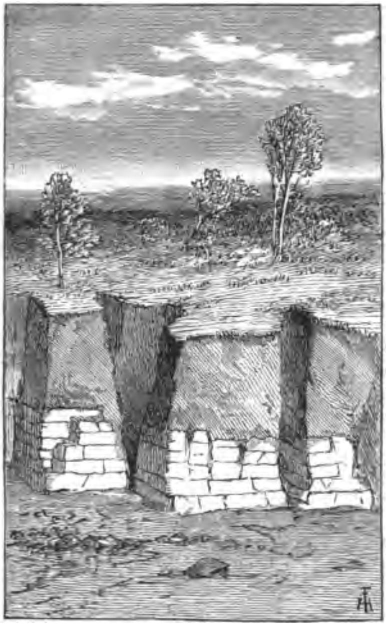


Fig. 370.

175. Gypsum.—At Fort Dodge, Iowa, is an extensive deposit of gypsum—sulphate of lime—which crops out along the valleys, in a ledge twenty feet high. It is represented in Fig. 370. According to Prof. White, it rests unconformably upon the St. Louis limestone of the Lower Carboniferous, and it is older than the Cretaceous. Hence Prof. White thinks it probably belongs to the Mesozoic

Time. It covers an area of nearly thirty square miles. Gypsum, or plaster of Paris, is valuable as a fertilizer, and for casts and stucco work. It is now quarried at Fort Dodge, for building and other purposes, and a railroad station house is built of it. Being a soft stone without grit, it presents great attractions to

> "rural carvers, who with knives deface
> The panels, leaving an obscure rude name,
> In characters uncouth, and spelt amiss."

176. **Cretaceous Period.**—Rocks of this Period are found in the north-western part of Iowa, and south-western Minnesota. Small patches of Cretaceous rocks are seen in the western and south-western parts of Iowa. The formation in Iowa is divided, by Prof. White, as follows, beginning above:

Inoceramus beds, 50 feet in thickness.
Woodbury sandstones and shales, 150 feet in thickness.
Nishnabotany sandstone, 100 feet in thickness.

177. The lowest and oldest of these is the Nishnabotany sandstone, named from the stream of that name in Iowa, on the east branch of which the rocks are seen. At Lewis, in Cass County, the sandstone is of a dark-brown color, and firm enough in texture for building purposes; but generally the rock is too soft for use. The same sandstone appears in Guthrie and Montgomery counties.

178. The Woodbury sandstones and shales are best seen in Woodbury County, in the neighborhood of Sioux City. Here the sandstone serves a purpose for common masonry, and the shales for pottery.

Fig. 371, on the next page, presents a view of the Cretaceous rocks as they crop out in the hills bordering the Sioux River, in Woodbury County.

Fig. 371.

179. The Inoceramus beds overlie the Woodbury beds. They are calcareous, but too hard to be chalk, and not hard enough to be limestone. They are used, however, for the production of lime. The name is derived from a fossil shell, which is abundant, the *Inoceramus problematicus* (Fig. 372, ⅓ nat. size). An oyster, *Ostrea congesta*, is somewhat abundant. The Inoceramus is sometimes found in the underlying Woodbury shales; also leaves of willow (*Salix Meekii*), and of sassafras (*Sassafras cretaceum*). The latter is shown in Fig. 373.

Fig. 372.

180. In other portions of the United States the rocks of the Cretaceous Period are very largely developed. They extend from New Jersey along the Atlantic border to South Carolina, and are widely spread over the Gulf States. From Texas they extend northward to the upper Missouri River, and westward, almost indefinitely, through Dakota, Wyoming, Colorado, and Utah. They are also found on the Pacific border.

The coal-bearing rocks of Colorado, Wyoming, and Utah are by many assigned to the Cretaceous Period, while others class them with the Tertiary, a later formation.

The plants, according to Lesquereux, our most eminent authority on palæontological botany, indicate a Tertiary age; while, on the other hand, the animal fossils appear to be of Cretaceous age. Prof. Cope thus sums up this interesting case:

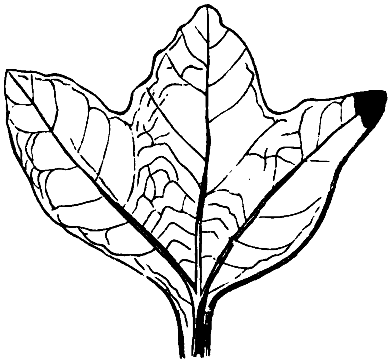


Fig. 373.

"There is, then, no alternative but to accept the result *that a Tertiary flora was contemporaneous with a Cretaceous fauna*, *establishing an uninterrupted succession of life* across what is generally regarded as one of the greatest breaks in geological time."

181. The most remarkable animal forms in the Cretaceous rocks of the West are the saurians, some of which were snake-like lizards of enormous length. Prof. Cope estimates the *Leiodon proriger* of Kansas to have been, at least, seventy-five feet long.

A saurian, called by Prof. Marsh the *Atlantosaurus immanis*, is said by him to be "vastly larger than any other animal, either recent or fossil, hitherto described." The femur, or thigh bone, is over eight feet long, with a transverse diameter, at the larger end, of twenty-five inches. If proportioned like the crocodile, the length of the *Atlantosaurus* "would be about one hundred and fifteen feet!" The bones of this monster were found in the rocks of the Upper Jurassic Period in Colorado.

Thirty-seven different species of reptiles, varying from ten to eighty feet in length, have been found in Kansas alone. Four of these were flying lizards, one of which measured eighteen feet between the tips of its wings, while another, the *Pterodactylus umbrosus*, covered nearly twenty-five feet with its expanded wings.

Fig. 374 represents the skeleton of a European form of pterodactyl—*Pterodactyl crassirostris.* The part lightly shaded represents a wing.

Fig. 374.

The bones of the pterodactyl were hollow, like those of birds, but in the structure of their teeth, claws, etc., they were true reptiles.

Another form is seen in Fig. 375, the *Rhamphorhyncus Bucklandi*, restored by Phillips, copied from Le Conte.

The dinosaurians (terrible lizards) of the Cretaceous were of large size, and, according to Marsh, "most of them walked erect, on their hind feet alone, like modern struthious (ostrich-like) birds. One of these monsters, (*Titanosaurus montanus*), from Colorado, is by far the largest land animal yet discovered; its dimensions being greater than was supposed possible in an animal that lived and moved upon the land.

Fig. 375.

It was some fifty or sixty feet in length, and, when erect, at least thirty feet in height. It doubtless fed upon the foliage of the mountain forests, portions of which are preserved with its remains." A form allied to the dinosaurus is found in New Jersey, called the *Hadrosaurus*.

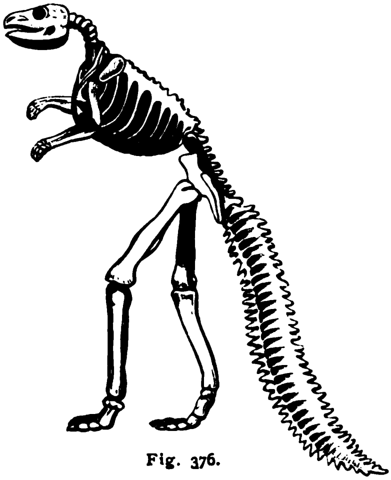


Fig. 376.

Fig. 376 shows this animal as restored by Hawkins, copied from Le Conte.

Its hind legs were very large, while the fore legs were relatively very small. It was twenty-eight feet long. Its teeth indicate that it was a vegetable feeder.

182. Remains of birds have been found in the lithographic slate, of Jurassic age, at Solenhofen, in Bavaria.

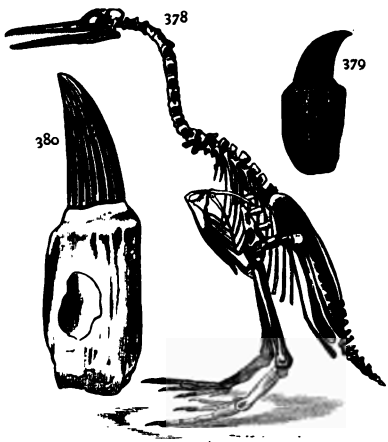

Fig. 377.

Fig. 377 represents a restored form of the *Archæopteryx macrura*.

It had a long, slender, vertebrated tail, quite unlike modern birds. It apparently had claws to its wings, like the bat.

One of the most interesting and suggestive discoveries of modern geology is that made in the Cretaceous beds of Kansas, by Prof. Marsh, of birds with teeth.

Fig. 378 represents the skeleton of one of these toothed birds, the *Hesperornis regalis* (royal western bird), as restored by Prof. Marsh. It was a water bird, with powerful swimming legs and feet, peculiarly adapted to rapid motion through the water. The length, from bill to toe, was nearly six feet. The wings were very small, and rudimentary, and could have been of no service for flight. Its teeth indicate carnivorous tastes, and its food was probably fishes.



Figs. 378-380.
Fig. 378, Hesperornis regalis, restored.
Fig 379, Tooth of same, magnified four times.
Fig. 380, Tooth, Mosasaurus princeps, reduced.

Fig. 379 represents its tooth, magnified four times. Compare this with a tooth of a saurian, in Fig. 380, and it will be seen to have a decided reptilian look. The Hesperornis had a long vertebrated tail.

Prof. Marsh describes another toothed bird from Kansas, under the name of *Ichthyornis dispar*, also a water bird, but only about as large as a pigeon. Unlike the Hesperornis, it had powerful wings, showing it to be capable of prolonged flight.

183. Cretaceous Plants.—Lesquereux has enumerated 130 species of plants, belonging to 72 genera, from the Dakota Group of Cretaceous rocks. Nearly all of these plants are of kinds which, so far as known, had never existed before. The larger part were *Angiosperms*, such as the oak, willow, beech, sassafras, sweet gum (*Liquid-amber*),

etc., etc. It was apparently the bursting into life of forests of new trees, and, what adds to the wonder, is the fact that many of the genera were represented by a greater number of species in those forests than represent the same genera to-day. There were, for example, two species of liquid-amber, six species of plane tree (*Platanus*), and three of tulip tree (*Liriodendron*), while it is said there is now living but a single species of each.

184. Dredgings in the deep Atlantic, bring from the bottom, in certain areas, a light colored, chalky mud, composed of organic forms, allied to those found in the Chalk beds of the Cretaceous, and it is believed that the era of chalk-making has not yet passed. Portions of the ancient chalk areas have been lifted up in the continental lands of America and Europe, but it is probable that in the deep Atlantic there may be beds of the same age, upon which deposits of chalk have been made down to the present time.

185. In closing the chapter on the Mesozoic Time, attention may be called to a few of its most marked characteristics. The Mesozoic is called the Age of Reptiles, and such we have found it to be. The wonderful discoveries of Marsh, Cope, and others, have revealed saurians which lived in the water, and others adapted to the land. Some walked upon their hind legs, and browsed upon the leaves and twigs of trees; others flew through the air like veritable dragons. These monsters must have been very numerous. In other parts of the earth, reptiles also abounded in the Mesozoic Time. But what do we find in our own time? Says Prof. Dana: "Since man appeared there is no reason to believe that there has been a single large Reptile in Britain. In India, or on the continent of Asia, there are but two species over fifteen feet long; in

Africa but one; in all America but three; and not more than six in the whole world; and the length of the largest does not exceed twenty-five feet."

The introduction of birds is another marked feature of the Mesozoic Time. The first known use of wings was by the insects of the Devonian Age, but so far as we know the Mesozoic were the first vertebrates to fly. These were the first birds with true wings and feathers. Some of them had teeth, others had horny beaks like modern birds. At the same time there were flying saurians, whose leathery, bat-like wings were ten or twelve feet long.

But perhaps no fact connected with the Mesozoic Time is of more interest than the apparently sudden incoming of the highest type of vegetable life in the Angiosperms of Nebraska. From the researches of Lesquereux it is evident that the forests of oaks, sweet gum, tulip tree, etc., with which were mingled stately palms, added great beauty to the landscape.

75

CHAPTER XVI.

Tertiary Age, or Age of Mammals.

186. Divisions of the Cenozoic Time.—We have already noticed two great geological Times—the Palæozoic, or time of ancient life, and the Mesozoic, or time of middle life. We now reach the Cenozoic, or time of recent life.

The Cenozoic Time is divided into two Ages, the Tertiary and the Quaternary. As has before been remarked, there was an early classification of the rocks, which gave us Primary and Secondary, but these terms have been abandoned, although the terms Tertiary and Quaternary are retained to designate the later formations.

187. The Tertiary rocks are divided, by Lyell, into three leading Periods, viz., *Eocene*, *Miocene*, and *Pliocene*.

Prof. Dana divides the Tertiary rocks of the United States into

The *Lignitic* Period, corresponding to the early Eocene;

The *Alabama* Period, corresponding to the middle and later Eocene;

The *Yorktown* Period, which includes the Miocene, and a part of the Pliocene; and

The *Sumter* Period, corresponding to part of the Pliocene.

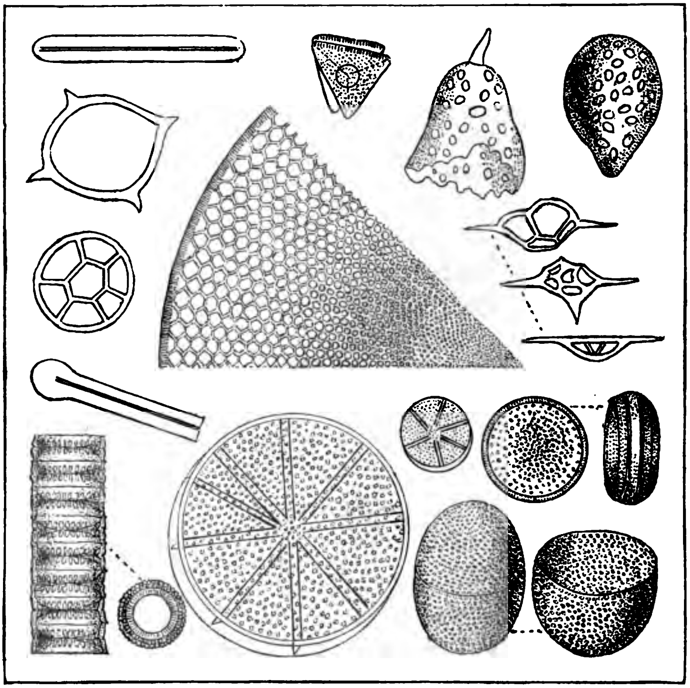
These are all southern names, except the Lignitic, which is derived from beds of coal, called *lignite*, from the Latin word *lignum*, wood.

As a general rule, the rocks of the Tertiary Age are less firm and hard than those of older ages, being composed of imperfectly compacted sands and clays, although firm sandstones and limestones are sometimes met with.

Tertiary coals, in large and valuable deposits, are found in Colorado, Utah, Wyoming, California, etc.

On the lower Mississippi River are beds of older Tertiary; and beds of the Miocene Period are found along the Atlantic coast, from New Jersey southward. In North and South Carolina are sands and clays of Pliocene age, rich in marine shells.

Fig. 381.



Diatoms, from Infusorial Earth, Richmond, Virginia.

Near Charleston, South Carolina, are deposits in the Eocene called the *Phosphate beds*, from the abundant nodules of phosphate of lime, which are largely dug for fertilizing land. These nodules contain Eocene fossils. Some suppose that there were once here beds of guano, from which the phosphoric acid was derived.

Near Richmond, Virginia, is a bed of infusorial remains, in places thirty feet thick, and extending for many miles. These remains are the silicious casts of very minute microscopic forms of Diatoms (plants), which in their growth secrete silica. Some of these Virginia forms are shown in Fig. 381, figured by Prof. Bailey.

Similar Infusorial beds are found in California, and they are not uncommon in the Old World.

The Tripoli polishing powder, first brought from Tripoli, has been found to consist almost wholly of the cast off shells of microscopic organisms.

188. Tertiary in the Interior States.—Beds, supposed to be of Lignitic or Eocene age, are found in western Kentucky, south-eastern Missouri, and in southern Illinois. Near Columbus, Hickman County, Kentucky, the Tertiary forms bluffs 200 feet high above the Mississippi River. Fig. 382, on the succeeding page, represents the bluff at Iron Banks, as delineated by Owen.*

It is a general rule, that where the Tertiary formation touches the Mississippi River, there are bluffs. At the beginning of the late war, one could have indicated, from a geological map, all the high and defensible points along

* NOTE.—Owen speaks of these bluff-beds as of Quaternary age, but many other geologists consider them Tertiary. Prof. Dana connects them with the Lignitic Group of the Eocene. Prof. Shaler colors this portion of the State as Tertiary on his Geological Map of Kentucky.

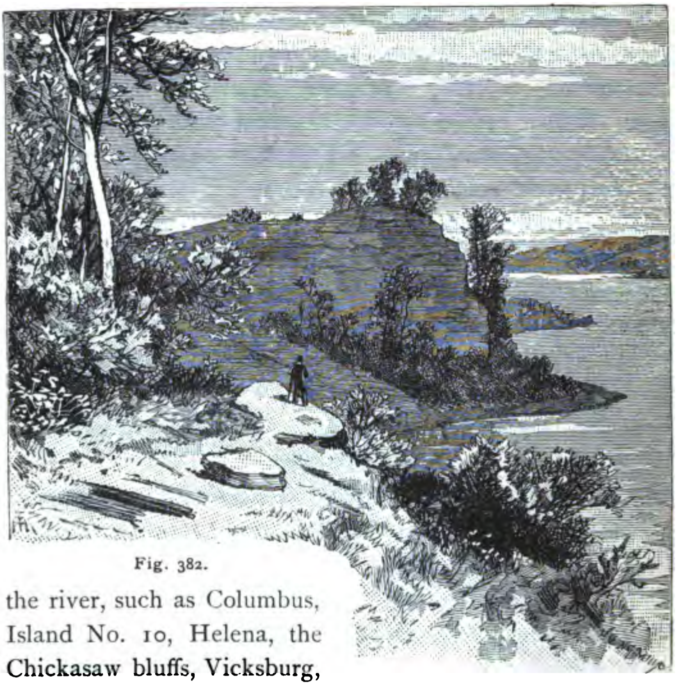


Fig. 382.

the river, such as Columbus, Island No. 10, Helena, the Chickasaw bluffs, Vicksburg, etc. Nearly all of these were afterwards fortified by the Confederate forces.

In Ballard and Graves counties, Kentucky, thin beds of lignite are reported, in strata similar to those near Columbus. In Pulaski County, Illinois, Prof. Worthen reports a green sand, containing Tertiary shells.

He found a shark's tooth near Caledonia, where a thin bed of lignite is seen at low water mark on the Ohio River. He has also discovered shark's teeth at Warsaw.

189. Fossils in the Tertiary rocks.—These are numerous, consisting of plants, mollusks, fishes, crocodiles, turtles, mammals, birds, insects, etc.

Plants.—We have noticed, in the last chapter, the sudden

appearance of a large number of the higher order of plants in the Cretaceous beds of the Dakota Group. If we accept the conclusion of Lesquereux, that the Lignitic Group of the West belongs to the early (Eocene) Tertiary and not to the Cretaceous, we find that the earlier part of the Tertiary was marked by a vast increase in the number of plants, many of which are of very great interest. Palms, which now only live in warm climates, are represented by many species. They are found as far north as the region of the upper Missouri. The number of Angiosperms, such as oaks, magnolias, dog-woods, etc., is very great. Some of these are represented by many species. For full description of Tertiary plants, the student is referred to the recent large work, entitled TERTIARY FLORA, by Lesquereux, published, with beautiful illustrations, by the General Government.

Mollusks.—The oceans abounded in all kinds of mollusks, and in some places the Tertiary rocks are full of them. They greatly resemble those now living, indeed, many are of the same species.

Fishes.—Fishes in great variety swam in the Tertiary waters. Sharks were very numerous. Their thickly enameled teeth, almost as indestructible as flint, are found in great numbers in the rocks. One of these is shown in Fig. 383. The *Carcharodon megalodon* was armed with teeth measuring six and a half inches long, and six inches wide at the base. Le Conte thinks this shark must have been from fifty to seventy feet in length.

Fig. 383.

Carcharodon angustidens.

Mammals.—One of the most remarkable of the Tertiary mammals was the *Zeuglodon cetoides*, a monstrous whale,

which lived in great numbers in the Tertiary seas, especially in Alabama. Fig. 384 represents one of its curious teeth, one third natural size, which is yoke-shaped, hence the name Zeuglodon.

Fig. 384.

Tooth of Zeuglodon cetoides.

Sir Charles Lyell, who twice visited this country, thus speaks of this animal: "The colossal bones of this cetacean are so plentiful in Clarke County, Alabama, as to be characteristic of the formation. The vertebral column of one skeleton, found by Dr. Buckley at a spot visited by me, extended to the length of nearly seventy feet; and not far off another back-bone, nearly fifty feet long, was dug up. I obtained evidence, during a short excursion, of so many localities of this fossil animal, within a distance of ten miles, as to lead me to conclude that they must have belonged to at least forty distinct individuals." One of the vertebræ, greatly reduced, is seen in Fig. 385.

Fig. 385.

Vertebra of the Zeuglodon cetoides.

The Zeuglodon was first thought to be a great saurian or lizard, but Prof. Owen, of London, determined it to be a whale from the teeth, and afterwards an entire skull was found, which proved the animal to be both a mammal and a whale. This is only one of hundreds of similar triumphs in the science of Comparative Anatomy won by Cuvier, Owen, Leidy, Wyman, Cope, Marsh, and others, in the study of fossil bones.

190. The Eocene beds of the Rocky Mountains have yielded to the indefatigable labors of Marsh, Cope, and others, many forms of new and remarkable quadrupeds. One of the most interesting of these is the *Dinoceras*, or animal with terrible horns, a name given by Prof. Marsh.

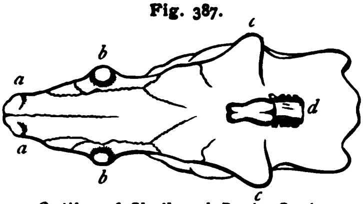
Fig. 386.

Dinoceras mirabilis.

Fig. 386 gives a face, or front, view of the skull—one eighth natural size. It shows three pairs of elevations, which Prof. Marsh supposes to be horn-cores, on which horns grew. It had two formidable incisor tusks, as shown in the figure.

Fig. 387 shows an outline of the same skull, viewed from above. The horn-cores are to be seen at *a*, *b*, and *c*. At *d* is shown the outline and relative size of the cavity which contained the few brains the animal possessed. Prof. Marsh states that this small cavity "proves conclusively that the brain was proportionately smaller than in any known mammal, recent or fossil, and even less than in some reptiles. It was, in fact, the most reptilian brain in any known mammal." The Dinoceras is more nearly allied to the modern rhinoceros than to any other living animal, but its brain was only one eighth of the size.

Fig. 387.

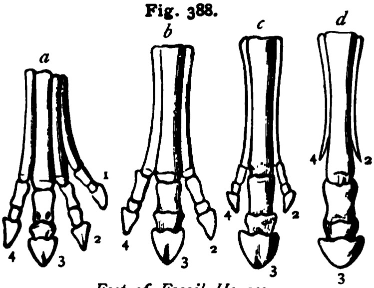


Outline of Skull and Brain Cavity.
One sixteenth natural size.

191. Fossil Horses.—The discovery of fossil forms of horses is even more interesting and important than that of the almost brainless dinoceras, for man has no better friend and helper among all the animals below him than the horse.

In Eocene beds, in the Rocky Mountains, there have been found the bones of a queer little horse, hardly larger than a fox, called the *Orohippus*. While the modern horse has one large toe enclosed in a hoof, the little orohippus had four toes on his fore feet, and three behind, all of which reached the ground, and were of use.

Fig. 388.



Feet of Fossil Horses.

In Fig. 388, *a* shows a fore foot of the orohippus with four toes, marked 1, 2, 3, and 4. In *b* we have the foot of the *Miohippus* with three toes. This horse was no larger than a sheep. Its bones are found in the Miocene of Oregon. In *c* we have the *Protohippus*, from the Pliocene beds of Nebraska. This has three toes, like the last, but two of them are dwarfed and shortened like the posterior hooflets of the modern deer and ox. This animal was about the size of a Shetland pony. The further dwarfing of these toes is seen in *d*, which represents the fossil horse *Equus fraternus*, and, indeed, the modern horse as well. Here the two side toes of the last are reduced to mere rudimentary splint bones. Prof. Marsh, who has made many of these discoveries, states that the modern horse occasionally has one of the ancestral hooflets developed, usually in the fore foot. The Equus fraternus was as large as the living horse of

our day. Thus there was not only an increase in size, but in speed; the latter, says Marsh, "being a direct result of the gradual modification of the limbs." It should be added that Prof. Marsh has found, in the lower Eocene, another little horse, called the *Eohippus*, no larger than a fox, which has on the fore foot four toes and decided anatomical hints of a fifth toe. Thus we have a regular series from a first five-toed horse down to a one-toed modern horse.

192. In the most recent of the Tertiary beds—the Pliocene — of the upper Missouri region, extinct forms of the camel, tiger, wolf, fox, elephant, mastodon, deer, and horse have been found, "a range of species quite Oriental," as Prof. Dana well remarks. Fossil monkeys have been found in Wyoming Territory.

Representatives of almost every form of modern life, animal and vegetable, have been found somewhere in the Tertiary formation. While very many species of plants and mollusks are identical with species now living; the fishes, reptiles, birds, and mammals, although of types now living, are not of the same species. Thus, the elephants can not be identified with the Asiatic and African elephants of our time.

Besides these larger forms of life, many insects have been found in the Tertiary rocks in the West. One of the most famous localities is Florissant, in Colorado. From the Florissant shales Mr. S. H. Scudder has described a fossil butterfly — *Perdryas persephone* — which is wonderfully well preserved, even to the microscopic scales on the wings. This is the first fossil butterfly found in America. The same naturalist has described, from the same shales, many new insects, including flies, locusts, beetles, etc., all beautifully preserved. From Crow Creek, Colorado, large numbers of clusters of the eggs of insects have been obtained. There

are about 2,000 eggs in each cluster, arranged in regular order, and "coated with a covering of what was presumably albuminous matter, which also surrounds each egg." These, says Mr. Scudder, are "the first insect eggs that have been found in a fossil state." Dr. A. C. Peale has recently discovered, in Wyoming Territory, a limestone covered with the petrified cases of caddis-flies. The cases are covered with "minute, rounded, water-worn pebbles, apparently of quartz."

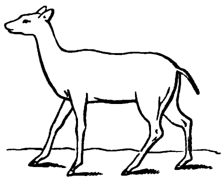
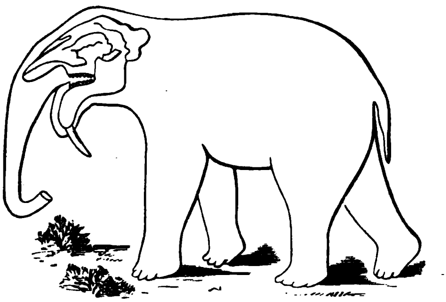


Fig. 389.

From the Florissant shales of Colorado, Prof. J. A. Allen has recently described a sparrow-like bird. It is in fine preservation, showing distinctly the feathers, claws, bones, etc. Prof. Marsh has also described a fossil bird, allied to the woodpeckers, from the lower Tertiary of Wyoming.

193. Foreign Tertiary Fossils.—In the Tertiary rocks of Europe, many interesting animals have been found.

Fig. 390.



Dinotherium giganteum.

Fig. 389 represents the *Anoplotherium* (*Xiphodon*) *gracile*, from the upper Eocene of Paris, as restored by Cuvier. It was a slender, graceful animal. In the European Miocene, many large quadrupeds, such as mastodons, mammoths, etc.,

have been found. One of the most remarkable of these is the *Dinotherium* (terrible wild beast), shown in Fig. 390, as restored by Dr. Brandt. It had a trunk like an elephant, but its lower jaw and tusks turned downward. There has been much speculation as to the uses of such tusks. The animal was doubtless aquatic in its habits, like the hippopotamus, and the tusks were probably used in tearing up the roots of water plants needed for food.

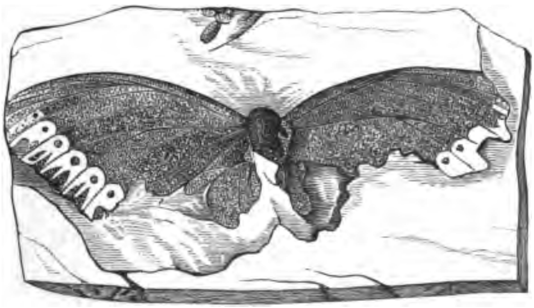
Fig. 391.

Harpactor maculipes — Heer.
Upper Miocene, Œningen.

Insects in great variety have been found in the foreign Tertiary beds. Prof. Heer enumerates 814 species from the beds of Œningen alone, and Sir Charles Lyell states that 1,322 different species have been found in the Miocene beds of Switzerland.

In Fig. 391 we see a fossil insect, in which the wings, two feelers, and some of the legs are preserved.

Fig. 392.



Vanessa Pluto.
Natural size. Lower Miocene, Radaboj, Croatia.

Fig. 392 represents a butterfly in a remarkable state of preservation, in which even the ornamentation of the fragile wings is retained.

In the Tertiary days there grew in many places in Europe trees allied to our modern pine or spruce, from which exuded a gum, which was soft and sticky at first, but afterwards became hard. Much of this gum was preserved in the shales which buried the coniferous forests, and in the fossil state is called *amber*. Such amber is often cast up by the waves upon the shores of the Baltic, and it is found to contain, in most beautiful preservation, flies, gnats, spiders, etc., which became entangled in the amber when it was soft and exuding from the trees. More than 800 species have thus been obtained.

CHAPTER XVII.

QUATERNARY AGE—DRIFT AND CHAMPLAIN PERIODS.

THE Quaternary Age is divided into three Periods, viz., the *Drift*, the *Champlain*, and the *Recent*.

194. **The Drift** is the first Period of the Quaternary Age. In many cities and towns there are areas, of considerable extent, of *made land*, so called because dirt, gravel, and small rocks have been brought from a distance and spread over the original surface. Sometimes low grounds and bays, like the Back Bay at Boston, have been filled, and made suitable for streets and houses. In nearly all of the Interior States, north of the Ohio River and of central Missouri, there is a deep covering of made land, composed of clay, gravel, and stones, brought by some agency from a distance, and spread over millions of acres. The larger stones are called *bowlders*, and the whole mass is called *drift*, because the materials are usually supposed to have been, in some way, drifted and left where they now lie.

The bowlders are sometimes very large, weighing many tons. They are found on high as well as on low ground. Perched upon high ledges they cause no little wonder in the minds of observers.

Fig. 393, on the succeeding page, represents the position of two bowlders on Mt. Pleasant, a high, bold ledge of Waverly sandstone, near Lancaster, Ohio. One is an

Fig. 393.

angular, unworn block of gneiss, about four feet long, and eighteen inches thick, on the summit of the cliff, 289 feet above the valley. The other is a rounded granite bowlder, nearly six feet in diameter.

There are no bedded rocks of granite or gneiss in Ohio from which these bowlders could have been broken. Indeed, there are no such rocks in Indiana, southern Michigan, Illinois, Iowa, and northern Missouri, and yet similar bowlders are found scattered over the surface of all these States. Where did these bowlders come from? In the nursery story of *Hop o' my Thumb*, we read that that bright little fellow, when taken into the woods to be abandoned by his parents, dropped pebbles along his path, and by these traced his way back to his home. By tracing, in the same way, the bowlders—which are only pebbles on a

larger scale—we find their places of origin to be far to the north, generally beyond the great lakes, where granite and similar rocks abound. Much of the gravel must have come from the same northern region, for it is composed of the same materials as the bowlders.

195. Structure of the Drift.—The Drift, sometimes not less than 200 feet thick, is made up of clay, sand, gravel, and bowlders, with occasional remains of trees. The clay beds often contain bowlders, and such clay is called *bowlder-clay.*

As a rule, the Drift in the Interior shows that it has been more or less assorted, by the action of water, and is consequently more or less laminated. Sometimes there is a confused or pell-mell structure, as in much of the Kettle Range Moraine, in Wisconsin, but we seldom find a good section of the Drift without evidence of a "crude stratification." In Fig. 394 we have a section of "original drift," in Knox County, Ohio, reported by Mr. M. C. Read.

Fig. 394.

	Feet.
Yellow clay, with drift-bowlders and pebbles, and flat fragments of local rocks . .	8
Blue bowlder-clay, unstratified, with rounded granite bowlders, gravel, and angular fragments of glacial rocks . . .	20
Laminated blue clay	2
Coarse stratified gravel	4
Coarse stratified sand	2
Yellow laminated clay	2
Blue laminated clay	2
Unstratified bowlder-clay	4
Stratified sand and gravel	

Section of Drift.

In Indiana, Mr. John Collett, of the Geological Survey of that State, reports the drift in Warren County as follows:

(1) Bowlder-drift, 50 to 75 feet thick.

(2) Bowlder-clay, with vegetable matter.

In Illinois, the general arrangement of the drift, according to Prof. Worthen, is:

(1) Soil and subsoil of reddish brown clay.

(2) Buff and yellow clays, with irregular beds of sand and gravel and bowlders, interspersed through the whole.

(3) Blue plastic clay, with small pebbles, often containing fragments of wood and trunks of trees of considerable size in the lower part.

In Missouri, Prof. C. G. Broadhead, of the Geological Survey, reports:

(1) Stiff brown, drab, and blue clays, with some rounded granite pebbles.

(2) Dark blue clay, with large bowlders of granite, red quartzite, and greenstone. Also, pockets and layers of sand, inclosing leaves and remains of trees.

In Iowa, the arrangement of the drift is about the same as in Missouri, with similar buried vegetation. In Minnesota the drift deposits often show a rude stratification, but few, if any, vegetable remains have been found in the bowlder-clay. In the Upper Peninsula of Michigan, the usual bowlder-clay underlies the other drift deposits. Dr. Rominger states that "a considerable portion of the drift deposits are not heaps of rubbish, but well stratified beds of clay, sand, and gravel, exhibiting, with plainest distinctness, the action of waves and water currents in their deposition." It is reported that the first native copper found by white men in the Lake Superior region, consisted of nuggets buried in the bowlder-clay. Such nuggets or bowlders have been found in the drift of nearly all of the Interior States.

196. Limits of the Drift.—No northern boundary of the drift has yet been ascertained. Drift deposits extend to Hudson Bay, and over Labrador. In the North-west, Prof. G. M. Dawson reports drift-bowlders 700 miles west of the Red River of the North, at an elevation above the sea of 4,050 feet. In Alaska, Mr. W. H. Dall explored the shores of Norton Sound, and traveled 1,300 miles up the valley of the Yukon without obtaining any evidences of glacial action, but proofs of such action appear in the Rocky Mountains. The southern limit of the drift has not been determined, but the Ohio River may be regarded as approximately the limit. In Missouri, drift deposits extend but a little way south of the Missouri River.

The map, Fig. 398, on page 218, represents, approxi-

Fig. 395.

Bowlders on an Iowa Prairie.

Fig. 396.

Grooves and Striæ, on Kelley's Island.

mately, the southern limit of the drift-bowlders. In south-eastern Ohio the true boundary line is probably farther from the Ohio River than the map indicates.

Finer drift materials, containing small bowlders, are found far down the Mississippi Valley. To these deposits Prof. Hilgard gives the name of the Orange sand. Prof. Dana regards this formation as belonging to the Champlain Period, which followed that of the drift. Bowlders of very considerable size are often met with along the southern margin of the drift area. A granite bowlder, near Lancaster, Ohio, measures, in its two diameters, 18 and 16 feet. In Sullivan County, Missouri, is a bowlder measuring 24 by 20 feet.

In Fig. 395 we see bowlders on an Iowa prairie, as described by Owen. The largest is 50 feet in circumference.

Bowlders are not derived exclusively from high northern latitudes, for we sometimes find them of fossiliferous limestones and other rocks belonging to the Interior States. In south-eastern Ohio, bowlders of coal are sometimes met with, especially in drift terraces along the rivers. These were evidently torn from coal seams, not very far north, for coal is too soft a material to endure the wear and tear of a long journey with fragments of granite and other hard rocks for traveling companions.

197. **Drift Striæ.**—Within the drift-covered areas we sometimes find the rocks planed down to a comparatively even surface, and marked with grooves and striæ.

In Fig. 396 we have a fine illustration of deep grooves in limestone along the shore of Kelley's Island, Lake Erie. While all the surface of the rock is planed, there is at one point a deeper erosion, as if the graving tool gouged more deeply there. The man in the picture is sitting upon a planed surface, and is looking down into the deep furrow below him. It is not uncommon to find similar cases in which a deep furrow ends abruptly. Drift grooves are quite numerous on Put-in-Bay, and on other islands in that neighborhood.

Drift striæ are not always uniform in direction upon the same striated surface.

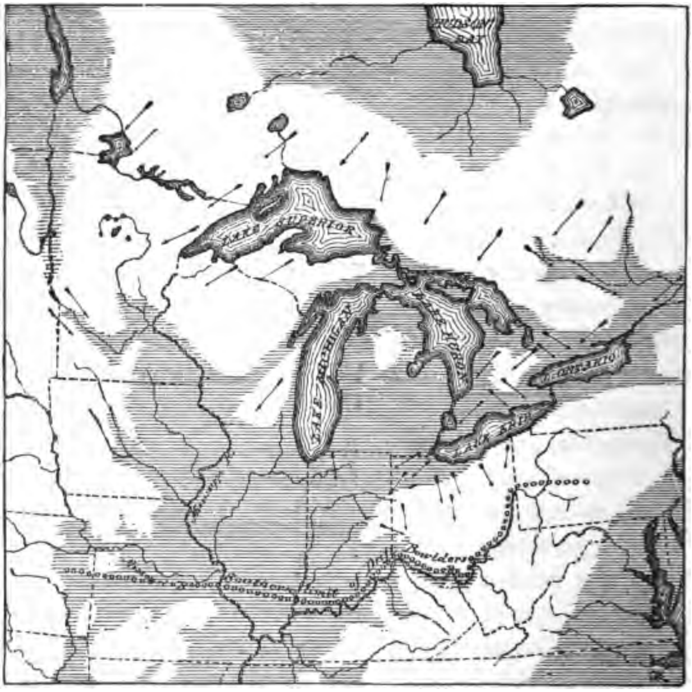
Fig. 397.

Glacial Striæ.

Fig. 397 represents drift scratches upon a planed surface of a sand-rock, in Fairfield County, Ohio. The lines, which are carefully drawn, vary in direction, implying a want of uniformity in the course of the scratching agent. The more common direction is that of the line on the bottom of the figure, which is N. 62½° W.

But while there are many minor local variations of lines, yet we usually find that the larger number of the striæ at any point have nearly the same direction. These general courses have been ascertained at many places quite widely separated, and a few of them are shown, by arrows, on the map, Fig. 398.

Fig. 398.



Direction of Striæ in Interior States and Canada.

The white parts of the map represent that portion of the land a thousand feet or upward above the level of the ocean. It will be seen that there is great diversity in the directions of the striæ. Perhaps the larger number point

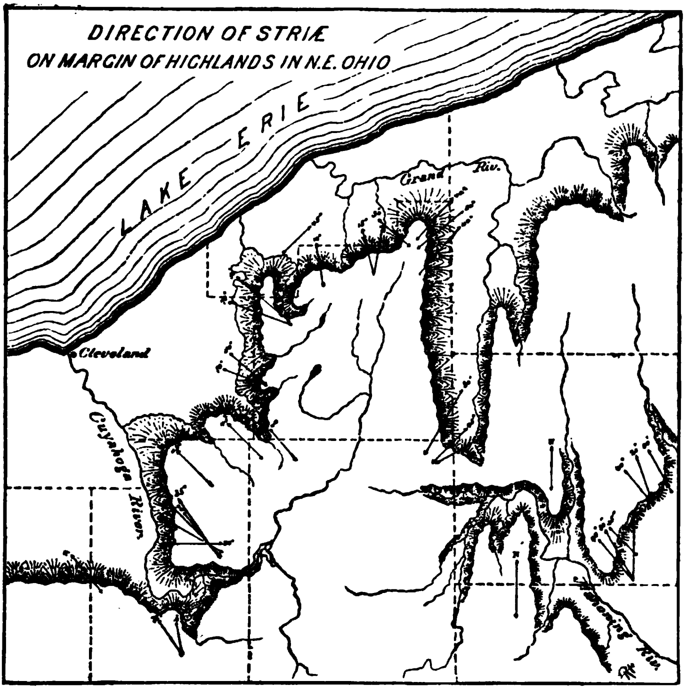


Fig. 399.

to the south-west, but in Ohio and Indiana the majority point to the south-east. The prevailing course in the Canadian highlands is from north-east to south-west; but in the region directly north of lakes Erie and Ontario, many of the striæ are from the north-west.

One of the most interesting illustrations of the varying directions of striæ is to be found in the north-east corner of Ohio, where they have been examined by Mr. M. C. Read.

The map, Fig. 399 represents, by the arrows, the lines of striæ along the margin of the highlands. It will be seen that they apparently radiate from the high grounds.

If we may suppose the plateau once covered with drift-snow and ice, with many glaciers moving down the slopes, to the surrounding low lands, we have a possible explanation of the divergent striæ. It is held by some, however, that the scratches were made by a great glacier which moved down from the North.

198. **Drift Agencies.** — Having noticed the leading facts connected with the drift, viz., the spread of clay, gravel, and bowlders over the surface, and the planing and scratching of the rocks, the inquiry at once arises—how came this over-spread of drift materials, and what made the striæ upon the rocks? Two leading agents have been assigned: (1) *Glaciers*, and (2) *Arctic currents with floating icebergs*. Both of these agencies are now to be seen in some parts of the world, doing a somewhat similar work.

199. **Modern Glaciers** are rivers of ice, flowing slowly in cold valleys. These valleys may be in high mountains, such as the Alps, or may come down to the sea, as in the Arctic and Antarctic regions. The ice is formed from the snows that fall on the higher lands, above the snow line, at the heads of the glacial valleys. In this way glaciers bring down the surplus snow, just as rivers bring down surplus water. In the Alps the snow line, on the south side, is about 8,800 feet above the sea, but the ice rivers sometimes flow 5,000 feet below this line before they are melted.

200. **The flow of ice** in glaciers has been explained in two ways. Prof. Forbes, of Scotland, held that ice under pressure is viscous, and moves like stiff, thick tar. Hence the glacier descends as a viscous mass down the valley.

Prof. Tyndall, in his experiments with ice, could not find in it any viscous property. By no application of force, however gently applied, could he make ice stretch or draw

out, like thick tar or molasses candy, but he found that ice under pressure would break into numberless fine pieces, and in this state adapt itself to any form of mold and freeze solid again. This refreezing is called *regelation.*

This peculiarity of ice in breaking and mending itself, Prof. Tyndall applies to the explanation of glaciers. The pressure from up the slope causes the ice to flow down the valley by an infinite number of fractures and regelations. If the glacier were a viscous mass, it should change its inclination without fracture, and move smoothly on its course. But in his observations on the Mer de Glace he reports the following facts: "Nearly opposite l'Angle there is a change of from four to nine degrees, and the consequence is the production of transverse fissures which render the glacier here perfectly impassable. Farther up the glacier, transverse crevasses are produced by a change of inclination of two degrees."

201. **Transporting Power of Glaciers.**—Glaciers are generally porters, and carry upon their backs the rocks and dirt which chance to fall upon them from the bordering slopes and ledges. At the same time they push along their beds, in a grinding, scratching way, such stones and gravel as may get beneath the ice. In this way a glacier often brings down large masses of loose materials, which are piled in irregular heaps at the lower end, where the glacier is melted. These heaps are called terminal moraines. The mud and finer particles are carried away by the streams of water which flow from the foot of the glacier. There are also lateral and medial moraines, these being the lines of rocks upon the glacier itself—the lateral on the sides, and the medial in the middle.

202. The friction of the gravel and stones under the glacier, upon the underlying rocks, is sufficient to scratch

and groove them, and sometimes to smooth and polish them—fine sand serving as the polishing powder.

In Fig. 400 we see a portion of the polished and scratched surface of limestone, as left by the file of a glacier in the Alps. The resemblance of these ice-smoothed rocks in the path of glaciers to the planed rocks in the drift regions of Europe and America, led Agassiz and others to believe that moving ice was the planing tool in both cases.

Fig. 400.

Glacial Striæ in the Swiss Alps.
Polished Limestone—Agassiz.

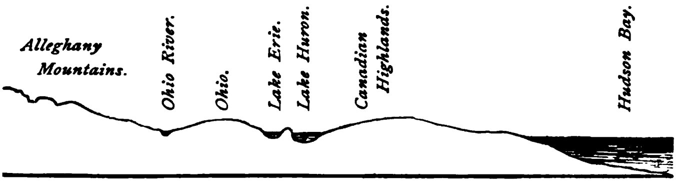
a White streaks or scratches, caused by small grains of flint frozen into the ice.
b Furrows.

203. According to the advocates of the glacier theory, a vast semi-continental glacier moved southward from the more northern regions, and caused all the grooves and scratches on the rocks, and also spread all over the drift area a vast mass of mud, sand, and bowlders coextensive with the glacial sheet. At a subsequent time, the area was depressed below the level of the ocean, and during this submergence the mass was worked over by currents of water and given the partially stratified condition which it now presents.

The existence of such a vast moving ice-sheet has been doubted by some on the ground that all modern glaciers flow down slopes, so that gravity greatly aids the descent, and there are to the north of the Interior States no lands sufficiently elevated to give the requisite slope for glacial

motion. The present relative altitudes of the lands, from Hudson Bay south through Ohio, are given in Fig. 401. The Canadian highlands are represented to be only about 1,600 feet in elevation. This is but little higher than the

Fig. 401.



Relative Elevations of Land.

highest land in Ohio. By reference to Fig. 401 it will be seen that a glacier moving south would have about as much up hill as down hill, and while gravity aids descent it hinders ascent.

Some of the advocates assume that in the time of the great ice-sheet the northern lands were much higher than now. Others think such elevation unnecessary, provided the ice and snow were piled high enough to give the requisite slope to the upper surface of the mass. It is stated by Prof. Le Conte, that it requires an inclination of from 2° to 3° to give motion to a glacier. A slope of this inclination ascending from the Ohio River, would give the glacier an almost incredible height before we reach the Canadian highlands. A rise of 2½° for only 200 miles would give an elevation of nearly nine miles. But Prof. Le Conte would not liken the great northern glacier to a modern mountain glacier, but to a polar ice-sheet, which he supposes to exist in Greenland, and to move *en masse* seaward. It is difficult to understand why a less inclination will suffice to move ice in Greenland than in the Alps.

204. The Iceberg Theory.—The rival theory is, perhaps, more strictly a *drift* theory than the one just given, for the term drift seemingly implies drifted materials.

The theory is that the drift area was submerged, and that northern currents of water flowed southward, carrying icebergs from which bowlders and gravel and dirt were dropped, while at the same time the currents pushed along the bottom sand and the finer sediments.

205. Icebergs are large masses of ice, broken from glaciers which in cold regions extend down to the sea.

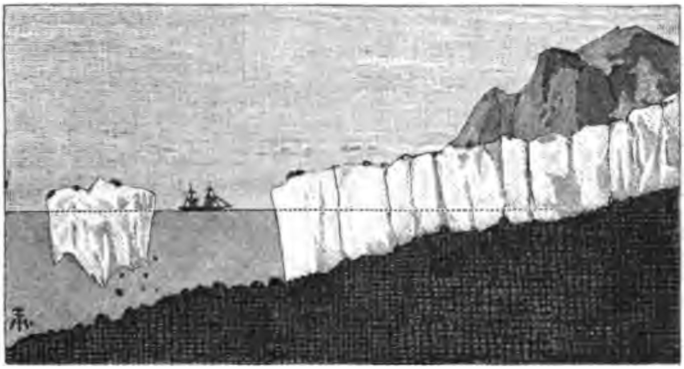
Fig. 402 represents a glacier filling an Arctic valley, and reaching to the sea in a fiord or bay. This glacier is two miles wide where it reaches the water, and is supposed to be from one thousand to two thousand feet deep

Fig. 402.

Glacier of Sermitsialik, Greenland—Hayes.

in the center. As the glacier moves down into deep water, immense masses of the ice are broken off, which float away.

Fig. 403.



Glacier entering the Sea.

Fig. 403 represents a lengthwise section of such a glacier, with the rock which forms its bed. At the sea end a large block of ice has broken off and started—"a raft which no man made"—on its voyage southward.

Some of the glaciers which come down to the sea are very large. The Humboldt glacier, in Greenland, is estimated to have a sea-front of forty-five miles. It is the parent of vast icebergs.

Commodore Wilkes and Sir J. Ross have reported immense vertical ice-cliffs skirting the Antarctic Land. The latter sailed for 450 miles along an unbroken front of ice-wall. This wall is shown in Fig. 404, page 226.

206. Size of Icebergs, and the work they do.—An iceberg in the Antarctic Ocean is reported to have been thirteen miles long. Very many are from half a mile to a mile in circumference, measured on the water line.

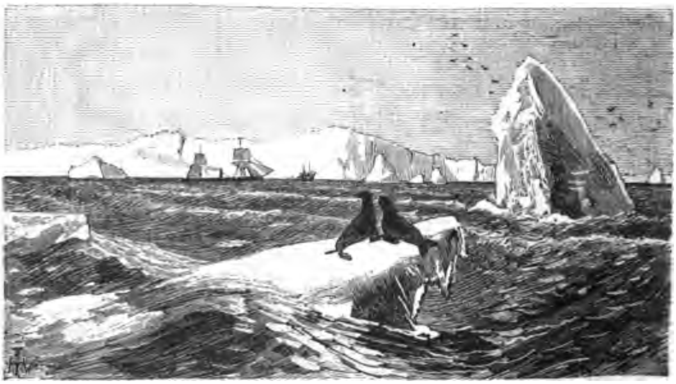
The specific gravity of solid ice is 0.918. This would cause a little more than one twelfth of an iceberg to be

above the water. But the ice of icebergs is seldom perfectly solid, and it is estimated that the portion above the water is from one seventh to one ninth of the whole mass. Hence, an iceberg 200 feet high above the ocean would have a submerged part about 1,600 feet deep. Captain Ross reported an iceberg aground in water 1,560 feet deep. Such vast masses of ice would be constantly striking the bottom of the ocean wherever the water was comparatively shallow. Fig. 405 represents an iceberg floating in the sea, and dropping upon the bottom rocks, etc., obtained from the land where it was part of a glacier.

Scoresby, the Arctic explorer, reports seeing many icebergs carrying burdens of earth and rocks, believed to be in weight from 50,000 to 100,000 tons. Such icebergs, moved by a current along the same general path, would scatter upon the sea bottom vast deposits of loose materials. The Newfoundland Banks are supposed to have been built up to a large extent in this way.

Besides the transportation of rocks and dirt by the ice-

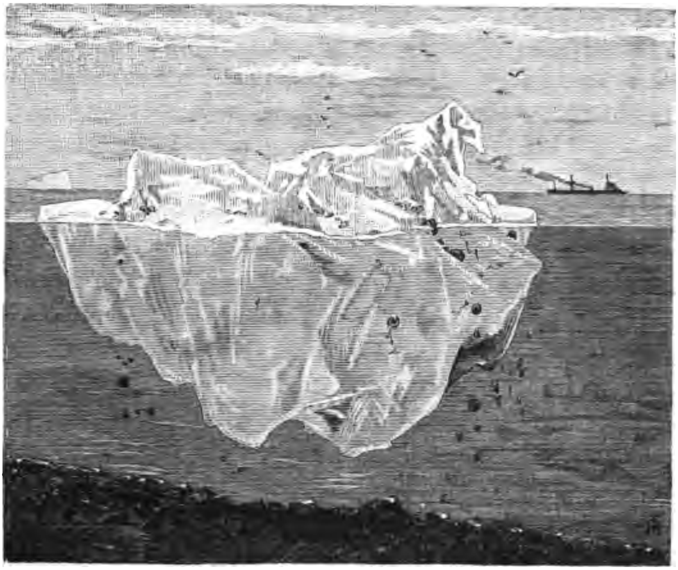
Fig. 404.



Ice Wall, Antarctic Land.

bergs proper, large quantities of similar materials are borne southward by the masses of shore-ice. The ice-belt which girts the shore in northern latitudes is detached in the

Fig. 405.



A Floating Iceberg.

summer. Dr. Kane states that in some localities on the shores of Smith Strait, Baffin Bay, this ice-belt is covered "with millions of tons of rubbish—greenstones, limestones, slates, rounded, angular, massive, and ground to powder." The same explorer reports finding ice rafts, thus loaded, floating far out at sea.

Icebergs gradually melt as they float southward, but quite rapidly as they come within the influence of the warm Gulf Stream. They sometimes reach 40° north latitude, and an iceberg with bowlders upon it has been seen in the Atlantic as far south as 36° north latitude.

207. The Number of Icebergs.—Icebergs are sometimes very numerous. Scoresby, Kane, and others, have counted hundreds in sight at one time. The polar current which flows southward along the eastern coast of North America sometimes brings vast numbers of them. Dr. Dawson presents the following facts: At the Straits of Belle Isle, for every iceberg entering the Straits there are five which do not enter but drift southward, and yet in a single day the Superintendent of the Light House counted in the channel of the Straits 496 bergs, the least of them sixty feet in height, some of them half a mile long and two hundred feet high. "Many of them," writes Dr. Dawson, "may touch the ground in a depth of thirty fathoms or more; so that if we imagine four hundred of these moving up and down under the influence of the current, oscillating slowly with the motion of the sea, and grinding on the rocks and stone-covered bottom at all depths from the center of the channel, we may form some conception of these polishers of the sea floor." Hence the advocates of the iceberg theory attribute to floating and grounding icebergs no small part of the work of scoring and planing the rocks within the area of the drift. In addition to this, it is claimed that shore ice may have done a similar work. "On the coast of Newfoundland," writes Mr. S. Milne, "ice forms on the shores from spray and occasional snows, enveloping and thus grasping firmly the stones and bowlders beneath, and attaining considerable thickness; and when a northern pack strikes it, it is pushed up shore, sometimes to a distance of two hundred yards. In the movement the rocky surfaces beneath are polished and scratched in a style precisely like the work of the glaciers. This shore ice, with its cargo of bowlders, stones, and gravel, is often drifted off as the tide rises, and

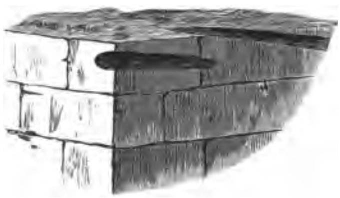
especially when a land breeze favors; and great lines of bowlders off the shore are thus made." Thus the shores of many latitudes would contribute their rocks to the common mass, to be worked over and commingled by grounding icebergs.

208. Icebergs and the Drift.—From these and similar facts it has been inferred that the drift period began with a gradual submergence of the northern drift area, and that over this area came the northern sea,

> "Whose icy current and compulsive force
> Ne'er feels retiring ebb, but keeps due on,"

and on this current were brought icebergs which were constantly grounding and grinding upon the bottom, while over the bottom where strewn mud, sand, and bowlders. The continued rasping of the icebergs upon the ocean floor would leave that floor, in the more shallow places, striated, and the uniformity in the direction of the currents would give a measure of uniformity to the courses of the striæ. If a hempen rope will make deep grooves in the stones used in the walls of canal locks, as shown in Fig. 406; or if the knees of devout pilgrims, upon the "sacred stairs" in the Vatican, at Rome, can wear down the hard marble, it may readily be supposed that immense icebergs, weighing millions of tons, drifting upon strong currents, would, in shoaling water, strike upon the bottom with great force, and, with the aid of loose rocks scattered upon the bottom, would rasp and groove the ocean floor. Scoresby has calculated that the blow

Fig. 406.



Grooves made by Ropes.

produced by one of the immense ice-fields is equal to that of 10,000,000,000 of tons. Le Conte speaks of single icebergs, and these not the largest known, as having a "volume near 500,000,000 cubic yards, which is about equivalent to a mass one mile square, and 500 feet thick." The impact of such vast bodies of ice would easily gouge out the rocks as shown in Fig. 396.

79R. 209. **The two Theories.**—The iceberg theory requires only two movements of the land, a downward one, and an upward one bringing the land back to its present elevation. The ice-sheet theory requires (1) an elevation of the northern land sufficient to produce the cold requisite for the formation of the great glacier, and also to give a slope down which it could move; (2) a depression of the drift area below the sea level, thus admitting the water over it, by which the drift materials, brought by the ice-sheet, were partially re-arranged. Some hold that in this sea were floating icebergs, the ruins of the ice-sheet, from which were dropped bowlders. The third movement was one of elevation, bringing the land back to its present level.

This is, perhaps, the simplest statement of the latter theory; but in the opinion of some, the movements were much more complicated.

The southern limit of the drift, according to the iceberg theory, would be where the ice would be melted by warm currents of water, supposed to flow from the Gulf of Mexico, aided by the sun and warmer temperature of the more southern latitude. This would make the southern line a very irregular one, as indeed it is.

According to the theory of a vast glacier, the southern limit of the drift would be where the warmth of a more southern sun would melt the ice, and prevent farther extension. The ice-sheet is supposed to have reached nearly

as far south as the Ohio River. Few, if any, traces of glaciers have been found in the Alleghany Mountains, which, in West Virginia, are not far south of the Ohio River, although these mountains are twice as high as the highlands between the Ohio River and Hudson Bay. Cold enough to permit the extension of an ice-sheet so near to the base of these mountains, would seemingly cover them with glacial snow and ice.

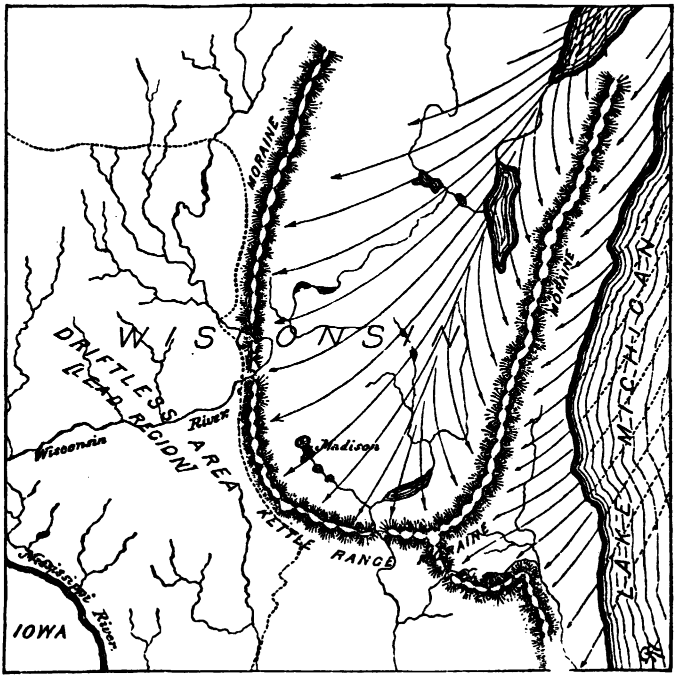
210. The drift deposits in the Interior States conform generally in their character to those found elsewhere in the Eastern States and Canada. Dr. Dawson, who has carefully investigated the drift of Canada, finds there, as we do in the Interior States, the bowlder-clay as the lowest of the deposits. It contains bowlders, and rests upon rocks which are often grooved and polished. As proof of the marine origin of the clay, he finds in it many marine shells of Arctic species. The bowlders are sometimes covered with a crustacean (*Balanus Hameri*), and with Bryozoa, showing that they had for some time quietly reposed at the sea bottom before being buried in the clay.

Dr. Dawson has found, in the Canada drift, no less than 205 different species of shells, radiates and articulates, with a few vertebrates and a few plants. Nearly all of these are forms now represented by living ones of the same species, inhabiting the northern part of the Gulf of St. Lawrence, and the Labrador coast. They are northern or Arctic species. As yet, no shells have been found in the drift of the Interior States, but living marine forms of Arctic type, obtained by dredging in the deep waters of Lake Superior, indicate that at one time the lake basins were submerged under currents of salt water from the Arctic regions.

211. It has been held that the lake basins were themselves excavated by glaciers. Lake Superior is a thousand

feet deep, and is formed in rocks, for the most part very hard. An ice-sheet, moving southward, would encounter high rocky lands on the southern margin. The deeper the

Fig. 407.



Kettle Range Moraine, Wisconsin.

lake basin became, and the higher and more opposing became this southern rim, the more the bottom of the glacier would be retarded in its motion, and the less able to remove the chips such a vast graving tool as a glacier would make. These unremoved, the process of deepening would stop. It is furthermore difficult to grant to an ice-sheet the power to dig out basins so extensive and profound, and, at the same time, withhold from it the

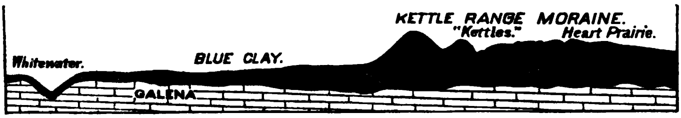
power to plane down hills of comparatively soft rocks which lie in its path. The better supposition is that the chief inequalities of surface within the drift area existed before the drift period, and that the mantle of drift materials—the *made land*—was spread over hill and valley and prairie, as snow is spread over the ground, hiding inequalities often, but not causing them

212. Terminal Moraines of the Drift.—At the lower or melting end of modern glaciers we find heaps of loose rocks, gravel, etc., but along the southern limit of the great drift area, in the Interior States, there is nothing corresponding to a terminal moraine. On the other hand, the quantity of drift materials is here much less than farther north, and it is probable that in the spread of the drift, from Lake Superior to the Ohio River, there is a gradual diminution of quantity as we go southward. This would be expected if we adopt the iceberg theory, but not if we accept the ice-sheet theory.

The most interesting illustration of a terminal moraine in the Interior States is in Wisconsin, shown in the map, Fig. 407. According to the view of Professors Chamberlin and Irving, this moraine was formed by two great local glaciers, moving as indicated by the lines and arrows on the map. One glacier filled the depression of Lake Michigan, and the other the valley now occupied by Green Bay, Lake Winnebago, and Fox River.

A cross section of the moraine is seen in Fig. 408.

Fig. 408



Profile from Whitewater to Heart Prairie, Wisconsin.

The moraine is from one mile to ten miles wide, and its highest peaks are 300 feet above its base. It is a vast uneven mass of clay, sand, gravel, and bowlders, but showing, in places, a "rude stratification."

In north-western Ohio, Mr. G. K. Gilbert reports two narrow ridges, sweeping in large curves across the Maumee River, which he regards as true moraines, produced by a south-western spur of a great retreating northern glacier.

213. Drift in valley terraces.—Deposits of drift materials are found along the borders of streams whose head-waters are within the drift area. They generally constitute terraces, sometimes 80 or 100 feet above the present beds of the streams. They are composed of drift sands and gravels, and often contain bowlders of considerable size. Wells dug in them sometimes encounter blue clay with bowlders and wood. In valleys, like that of the Muskingum River, in Ohio, lying chiefly within the Coal-measures, the terraces often contain small bowlders of coal. All the fossiliferous rocks lying north of such terraces contribute to the mass, and very good fossils could be obtained from these terraces.

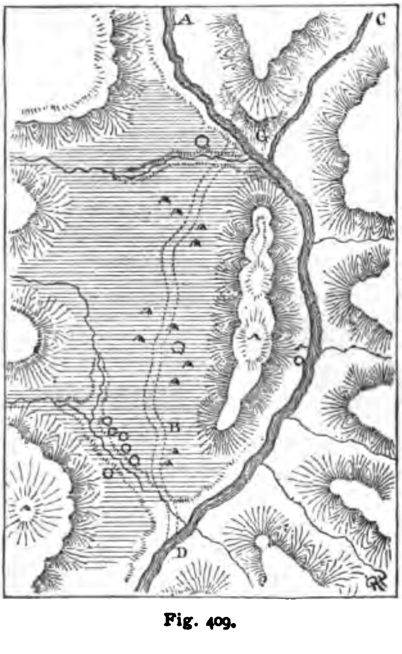


Fig. 409.

Fig. 410.

River Terrace and Mounds.

In some cases these drift materials have choked up the old valleys, and streams have been diverted from their original channels. This is shown in Fig. 409, in which the Hocking River, *A*, near Salina, Athens County, Ohio, which once flowed past *B* to *D*, was forced, by the mass of drift filling its old valley, to break through a low gap at *G*, and occupy the valley of Sunday Creek, *C G D*. The old valley, is now completely filled with drift, to the depth of eighty feet or more. Where was once the valley is now a beautiful plain, upon which the ancient mound-builders constructed many large earthworks.

These drift terraces, in Ohio and other Interior States, were attractive locations to this early race, and upon them we find their earthworks, as shown in Figs. 409 and 410.

214. These valley drift terraces are generally supposed to belong to the Champlain Period, a period to be noticed hereafter. Some regard them as the remains of gravel bars and sandy flats, formed by the high water in the streams, caused by the melting of the great ice-sheet. In whatever way the transporting power originated, it appears probable, in many cases at least, that the same agency that spread the general mantle of drift over the Interior States also distributed the drift along the valleys to the south. This may be illustrated by Fig. 411, which represents a river having its headwaters within the drift area, *A*. This drift extends down the valley by a narrowing tongue, until at *B* it is broken up into isolated river terraces.

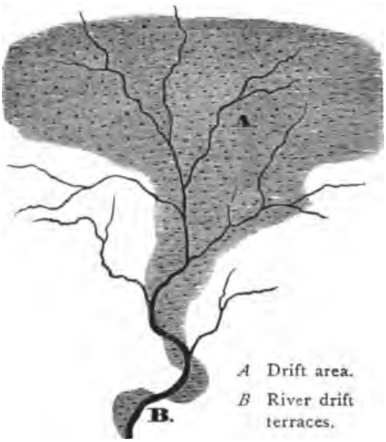


Fig. 411.

We find at *B* the blue bowlder-clay, and the same arrangement of the drift materials as at *A*.

It is possible that there are, in the Interior States, terraces of the Champlain Period, but the river-valley terraces on streams flowing southward from the drift area are, it is believed, merely southern extensions of the drift proper.

In western Pennsylvania, drift terraces have been found 1,300 feet above the sea. In the slow emergence of the land from the waters of the Drift Period, it would not be strange to find terraces at any elevation where drift mate-

rials lay. But doubtless the terraces on the higher lands have been for the most part obliterated.

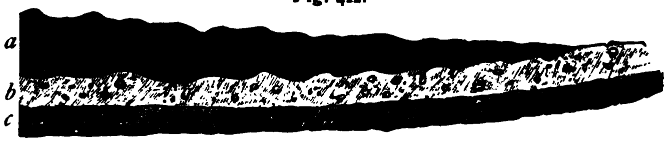
215. Champlain Period. — This period derives its name from marine deposits found on the borders of Lake Champlain, in Vermont. According to Prof. Dana, this period is marked by the melting of the ice of the Drift Period, and the resulting waters brought large quantities of clay, sand, and gravel, and left them in the valleys. The finer materials were gathered out of the wide-spread drift accumulations, and dropped along streams and in the beds of lakes.

While, according to the same authority, there was in the Drift Period an elevation of northern lands, in the Champlain Period the lands sunk below the level of the ocean. The proof of the latter fact lies in the existence of deposits with marine shells, 200 feet above the sea, on the coast of Maine, and 500 feet high in Canada. When the land rose again, the waters of the rivers and lakes carved out of the previous Champlain deposits the terraces which abound along the rivers and lakes of the Northern States.

216. Lake Ridges. — Along the Great Lakes are long ridges, at various elevations above the present water levels, made when the waters were much higher than now. These are true ridges, narrow and with a double slope from the center, which distinguishes them from terraces. In regions where the land is marshy or wet, these ridges, being dry, are chosen sites for buildings and for roads. From the fact that these ridges are found at higher elevations on the northern shores of the lakes, it has been inferred that the land in the higher latitudes had settled down more than in the region south of the lakes. It is claimed that similar ridges are now being formed by the action of the waves along the more sandy portions of the lake margins.

217. Bluff or Lœss Formation.—In western Iowa and north-western Missouri are large fresh-water deposits of brownish loam, containing considerable lime, which form the peculiar bluffs bordering the Missouri River. Hence the name Bluff Formation. It has sometimes been called the *Lœss*, a European term, applied to similar deposits. It

Fig. 412.



Section of Rock in Iowa — Bluff Formation.

is believed that subsequent to the Drift Period a large fresh-water lake covered a portion of the Missouri Valley. Into this lake the upper Missouri River brought its abundant mud, which settled to the bottom, and thus formed the deposit. This deposit rests upon the drift, as shown in Fig. 412. Here the upper bed, *a*, is the Bluff Formation, which rests upon the drift, *b*, underneath the latter are the rocks of the upper Coal-measures, *c*.

The Bluff Formation is well seen at Council Bluffs, and along the Missouri River, above and below. The deposit is sometimes 200 feet thick. From the singular appearance of the bluffs it might be inferred that the lake was suddenly drained, and that the river cut a deep channel in the ooze of mud at the bottom, and, as a consequence, the mud on either side caved in, leaving the peculiar indentations of caved banks. The mud rapidly dried and hardened, and became so firm that it has since been little subject to waste from rains. These bluffs present a very singular and unique appearance, and there is probably nothing like them elsewhere in the Interior States.

CHAPTER XVIII.

QUARTERNARY AGE—RECENT PERIOD.

218. After the glaciers and icebergs of the Drift Period had melted, and the land had emerged from the waters, and become dry and fitted for re-occupation, animals of various kinds appeared and made the Interior their home. It is quite probable that some of them returned from places south of the glacial area where they and their ancestors had lived during the Drift Period.

Conspicuous among the animals whose remains are found in the Interior States are those huge mammals, the Mammoth and Mastodon.

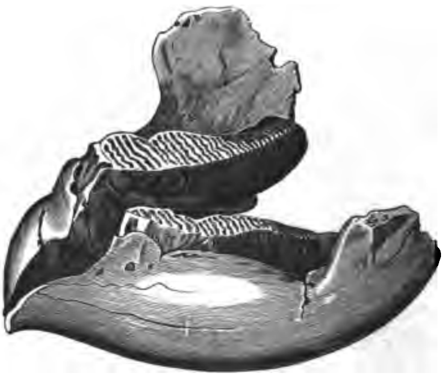
219. Mammoths were true elephants, allied to existing elephants. The two leading species of the Recent Period are the *Elephas primigenius*, and the *Elephas Americanus.* The former had a very wide geographical range, and its remains have been found in Europe, Northern Asia, and North America. There must have been large herds of them in England for their teeth are dredged up in great numbers by fishermen along the coast.

In Eastern Siberia, the tusks of this species are dug up and sold for ivory. In 1799, a fisherman and ivory hunter saw on the bank of Lake Oncoul, near the mouth of the Lena River, a huge, shapeless mass, projecting from the face of a high ice-bank. This mass, after some years,

was thawed out from its imprisonment in ice and sand, and fell from the high bank. The fisherman visited the spot again in 1804, and found it to be the body of a huge elephant, the tusks of which he cut off and sold for fifty roubles,—about $37.50 of our money.

In 1806, a Mr. Adams, an employé of the Court of Russia, visited the spot. The flesh had been fed to dogs, and the place had been a rallying point for bears, wolves, and foxes, which had eaten their fill and left their tracks in the mud. He, however, found the head well preserved and the eyes remaining. The skin, which was for the most part saved, was covered with a reddish wool intermixed with black hairs, and a long mane covered the neck. Measurements showed the animal to be nine feet four inches in height, and sixteen feet four inches long, exclusive of the tusks, which measured nine feet six inches along the curve. All that remained of the animal was taken to the Museum at St. Petersburg.

Fig. 413.



Lower Jaw of Elephas Americanus.

Recovered bones show that many individuals of this species of mammoth were larger than the one described above.

The form of mammoth more commonly found in the Interior States is the *Elephas Americanus*. The teeth are often found, but other parts of the skeleton are more rare.

Fig. 413 represents a lower jaw, containing two teeth on each side, dug up in the Hocking Valley, sixteen feet below the surface. The flat surface of the teeth was the grinding surface.

We have in Fig. 414 the inner side of one-half of the same jaw, from which a part of the bone is gone, disclosing the structure of the teeth, especially of the large molar. This tooth is seen to be made up of vertical plates of enamel. There are now twenty of these plates, and several have been lost from the rear end. Only the front end of the tooth came into use. Under the grinding surface, toward the front, the jaw is very thick and strong, but behind it is very thin, scarcely more than a quarter of an inch thick.

Fig. 414.

Fig. 415.

Grinding Surface of Molar.

Fig. 415 gives an exact representation of the grinding surface of the molar referred to. The elevated rings and links are the worn off tops of the enamel plates. The dentine, or bone between the plates, is softer than the enamel, and wears away faster. This keeps the tooth always dressed like the roughened millstone, and ready for use.

Fig. 416 represents the larger part of a shoulder-blade of a mammoth found at Waterford, Ohio. The concave

end is so large that the ball of the humerus must have been nearly ten inches in diameter.

220. The **Mastodon** was like an elephant in almost all respects except in its teeth. These, instead of being formed of vertical plates, like those of the mammoth, were covered over the top with enamel like a human tooth. The crown is made up of conical elevations somewhat nipple-shaped, and this shape of the tooth gives the name *Mastodon* to the animal. Fig. 417 represents such a tooth found in Ohio. The crown is somewhat worn and the dark spots show where the enamel is gone.

Fig. 416.

Shoulder-blade of Mammoth.
Muskingum Valley, Ohio.

Fig. 418 presents the entire skeleton of the *Mastodon Americanus.* Mastodons must have roamed in considerable numbers among the hills and valleys of the Interior States, for the teeth and portions of the bones of many individuals have been found. Big Bone Lick, in Kentucky, received its name from the bones of this huge animal.

Fig. 417.

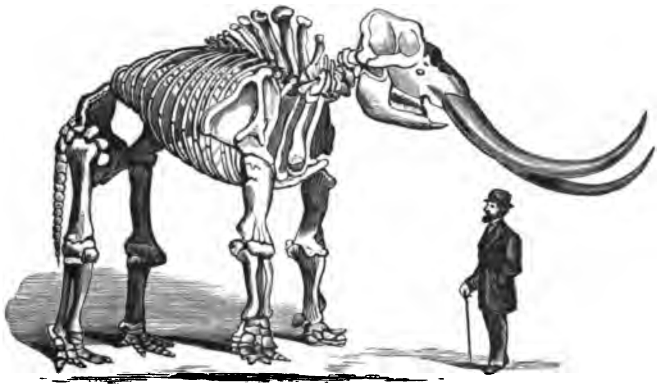
Tooth of a Mastodon.
One-fifth natural size.

Several years ago, some large skeletons of the Mastodon were dug up in a marsh near Newburgh, N. Y. It is supposed that the animals had ventured into the bog and had been mired.

The late Dr. J. C. Warren, of Boston, obtained one of them, which he set up in his private museum. It is

eleven feet high, and seventeen feet long to the base of the tail. The length of the tusks is twelve feet, of which

Fig. 418.



Skeleton of the Mastodon.

two and one-half feet are inserted in the socket. The estimated height of the animal, when living, was from twelve to thirteen feet, and the whole length, adding seven feet for the horizontal projection of the tusks, from twenty-four to twenty-five feet. When dug up there was within the ribs a mass of blackened vegetable matter composed in part of twigs of spruce and fir. This, it is supposed, was its food.

Fig. 419.

Bootherium bombifrons.

It is quite probable that both the Mastodon and Mammoth in the United States had a hairy covering.

221. Extinct Oxen. — Some extinct forms of oxen, allied to the musk-ox, are believed to have lived at the same time with the Mammoth and Mastodon. Fig. 419

represents the front view of a skull of an ancient ox found at Big Bone Lick, Kentucky. It is called by Dr. Leidy the *Bootherium bombifrons*. A side view of the same, Fig. 420, shows how depressed or lopped the horns were.

Fig. 420.

Bootherium.
Side view.

A specimen of *Bos latifrons*, from Ohio, is reported to have horn-cores twenty inches in diameter, and the tips of the horns must have been ten feet apart.

Dr. Leidy also describes an extinct form of buffalo or bison belonging to the same period.

Bones of an extinct horse, somewhat larger than the modern horse, have been found. The teeth of *Equus major* from Illinois bluffs, not far from St. Louis, have been described by Dr. Leidy.

A large animal of the sloth tribe belonged to the same period. President Jefferson named it *Megalonyx*, or *large clawed animal*, from bones found in Greenbrier County, West Virginia.

Bones of this animal have been found at Big Bone Lick, Kentucky, and at many other points, showing that the beast had a wide range. Fig. 421 shows a claw of half the natural size. The whole animal must have had the size of an ox.

Fig. 421.

Claw of Megalonyx Jeffersonii.

The beavers of that day were more than twice the size of modern beavers. Fig. 422 shows a side of the lower jaw of one found in Ohio, which was named by Col. J. W. Foster the *Castoroides Ohioensis*. *B* is the top of *A*.

222. A few years since, Mr. J. H. Klippart obtained from an excavation at Columbus, Ohio, nearly complete skeletons of twelve individuals of a large wild hog, *Dicotylus compressus.* When this animal became extinct is not known. It might have lived after the advent of man.

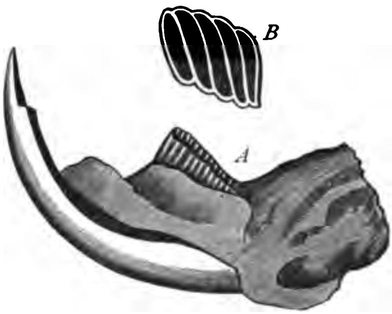


Fig. 422.

Remains of the reindeer have been found at Big Bone Lick, Kentucky, elsewhere. The bones of several kinds of birds have been found in Quaternary deposits. Among these Prof. Marsh enumerates two species of turkey from New Jersey.

The head of a whale—*Beluga Vermontana*, was found on the borders of Lake Champlain.

223. In other parts of the world, animals of this period appear to have been more numerous than in North America. "In South America," states Prof. Dana, "over one hundred species of extinct Quaternary quadrupeds have been made out. The bones occur in great numbers over the prairies or pampas of La Plata, and in the caverns of Brazil; and they include some thirty species of rodents (squirrels, beavers, etc.), species of horse, tapir, lama, stag; a mastodon, different from the North American; wolves, and a half a dozen panther-like beasts which occupied the caverns of Brazil; and among edentates (ant-eaters), twelve or fourteen species, related in tribe to the megatherium (sloth tribe), and a dozen or more related to the armadillo. They number more species than now exist in that part of the continent, and include far larger animals." The mega-

therium was a monster, eighteen feet long, with enormously large bones.

In Europe, the quadrupeds of the Quaternary Period were generally of more ferocious types. There were bears larger than the great grizzly bear of California, tigers larger than those of Bengal, hyenas in great numbers, leopards, etc., etc. In addition to these, there was a sort of tiger of peculiar fierceness, the *Machairodus*, whose canine teeth were sharp daggers, eight inches long. "This animal," says Owen, "was probably the most ferocious and destructive of its peculiarly carnivorous family." Besides these, there were horses, mammoths, rhinoceroses, hippopotamuses, deer, boars, etc., etc.

The bones of most of these animals have been found in caves, and with them the relics of man in stone implements, and there can be no doubt that man was a contemporary of these extinct species of quadrupeds.

79

CHAPTER XIX.

MAN.

224. All the forms of animal life appear to have their culmination and highest expression in Man, who is the natural ruler of the earth. He can subdue the lower animals, many of which, such as the horse, dog, ox, camel, and elephant, are trained to serve him. He has greatly modified many of the plants of the earth, and brought the grains and fruits to a high perfection. He traces the metals and their ores to their deep hiding-places, and converts them to almost innumerable uses. Light, heat, and electricity have become his obedient servants. The range of his scientific investigations is almost without limit, and his diversified arts make life more tasteful and desirable. In addition to his intellectual powers, he possesses a moral and spiritual nature, and thus stands immeasurably above all other animals.

225. When did man first appear upon the earth? It is very certain that there are no traces of man or of his works in any of the older rocks. There was no man living to botanize among the magnificent plants of the Coal Period, nor to study zoölogy among the monstrous reptiles of the Mesozoic time. He has not lived very long upon the earth, for we find his remains only in comparatively recent

surface formations of soil and gravel, and in the accumulated debris of caves.

226. Indians.—The first European explorers found the continent of North America in possession of Indian tribes. How long these tribes or their ancestors had held the country is not known. We find their bones and implements at no great depth below the surface of the ground, and sometimes in caves and under shelving rocks. Fig. 423 represents an overhanging rock in Hocking County, Ohio, under which the author saw a pile of ashes one hundred feet long by thirty feet wide, and from two to three feet deep. In the ashes were found bones of many wild animals, nuts, fragments of pottery, arrows, and a large quantity of the seeds of *Chenopodium album*, a plant of the pig-weed family, carefully placed near a buried human body. This sheltering rock may have been resorted to for several hundred years, but the antiquity of the human remains found under it can not be great, and the same is doubtless true of all undoubted Indian remains found in caves and elsewhere in the United States.

Fig. 423.

79R **227. Mound-builders.**—In the Interior States lived a race anterior to the Indians, called from their works the

Mound-builders. They were more recent than the Drift, because many of their largest earth-works are built upon Drift terraces.

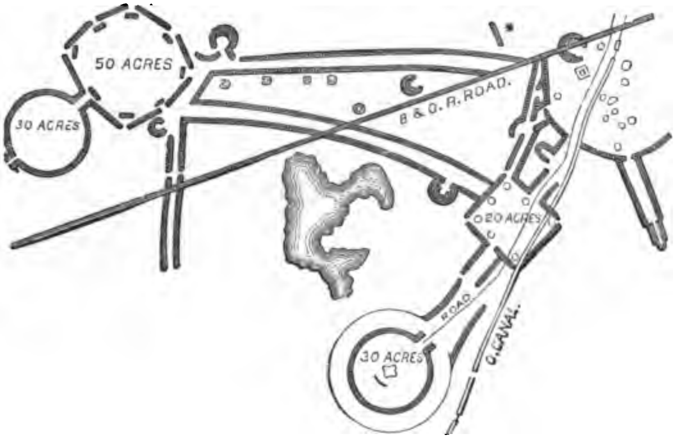


Fig. 424.

Fig. 424 represents the extensive earth-works at Newark, Ohio, as surveyed by Col. C. Whittlesey. The amount of earth heaped up in these works is simply enormous.

Similar works, although of less extent, are found in many parts of the Interior, but the population was evidently more dense in Ohio than elsewhere. The Mound-builders were an agricultural people, for an adequate food supply for so many workers could not have been obtained from the precarious resources of the chase. In their burial mounds we find various copper ornaments and implements, and the supply of copper must have come from the ancient copper mines of the Lake Superior region. The old workings in that region are very extensive. Lines of trenches along the veins of native copper have been traced long distances in the upper peninsula of Michigan and on Isle

Royale, the aggregate length of such trenches being estimated at one hundred and fifty miles. A mass of native (metallic) copper, weighing 6,000 pounds, was found in one of these trenches on Isle Royale, sixteen feet below the surface. It is represented in Fig. 425.

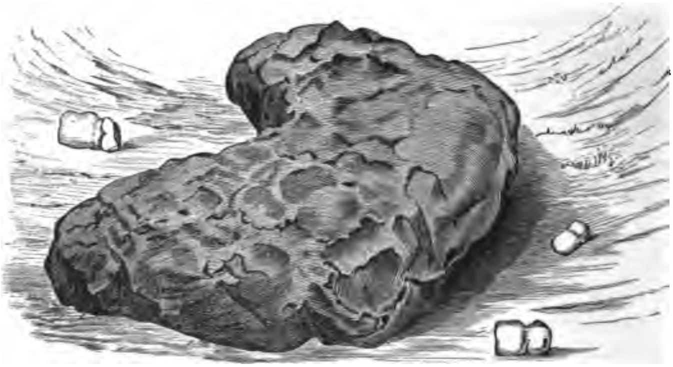


Fig. 425.

It shows the marks of the stone hammers by which the soft metal was beaten into ridges or feather-edges, which were broken off, and thus the copper was obtained for use. At the bottom of another pit on Isle Royale, a trench with smooth side walls had been quarried out of the solid rock, nine feet deep. The miners were following a vein of native copper eighteen inches wide.

On the land of the Minnesota Mining Company, on the main-land, a mass of copper weighing six tons was found in a trench five feet above the bottom, propped up on oak logs. The vein of copper underneath was five feet thick. The earth with which the trench is now filled had also become during the lapse of ages firmly packed around the mass. In Fig. 426 we see, in the portion lightly shaded, a longitudinal section of this ancient trench, and in the shaft, *A*, the detached block of copper. A hemlock tree

growing in the dirt thrown from the trench showed three hundred and ninety-five rings of annual growth.

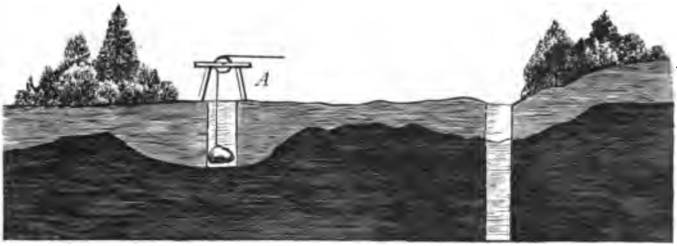


Fig. 426.

With a very short working season in so inhospitable a climate as that of Lake Superior, with no adequate local food supply, the work of mining must have proceeded very slowly, and consequently must have required, for such extensive excavations, a very long period of time. The many large flint quarries, such as are found on Flint Ridge, in Licking County, Ohio, indicate that the Mound-builders must have wrought in them for a correspondingly long time. These ancient quarries were found partially filled with earth, and covered with old forest trees at the time of the settlement of the Interior by the whites, and the Indians had evidently never wrought in them.

The Mound-builders must have passed away a long while ago, as shown by the waste of their mounds and of the ground on which they were built.

In Fig. 427 we see at *A* an ancient circle or "fort," in Athens County, Ohio, with its wall without and ditch within, a part of which has been removed, together with the brow of the high terrace on which it stands. The waste of the terrace and circle could not have been produced by any action of the little stream some distance away in the valley below, for it is evident that the stream

flowed where it now does in the days of the Mound-builders, since the large circle at *B* has been made by filling out the top of the bank where it had been washed away by the same stream. There is nothing to show that the brow of the terrace at *A* was removed by other agency than that of frost and rain, by which the sand and gravel were lowered particle by particle, an extremely slow process, and especially so during the long period when the surface was covered by forests after its abandonment by the Mound-builders. To a geologist this proof of the antiquity of the mounds is a very strong one.

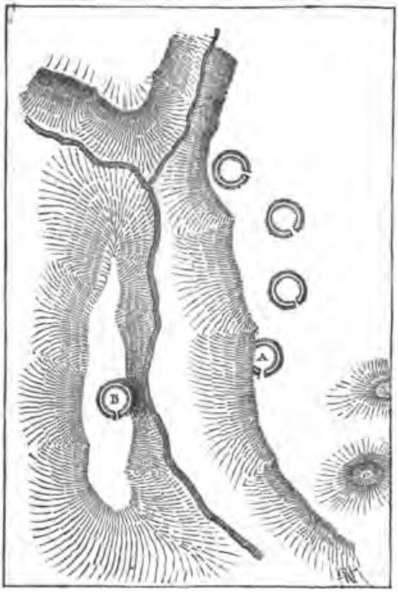


Fig. 427.

What races, if any, preceded the Mound-builders in the United States is not known. In New Jersey, in the valley of the Delaware River, the stone implements of such a supposed earlier race have been found in some gravel beds, which Dr. C. C. Abbott regards as beds of the later Drift. The exact age of these beds, however, has not yet been established.

228. In Europe human bones and stone implements have been found in caves, associated with the bones of the mammoth, rhinoceros, reindeer, cave bear, and other

species of animals now extinct, and it is evident that these animals and man lived at the same time. Chipped flints have also been found in gravel beds along the Somme and other rivers, with similar bones of extinct animals. Some suppose that these gravel beds are of the Champlain Period, which followed the Drift.

The skulls of the most ancient men found in European caves indicate an average amount of intellect. The skeleton of a man from the Cave of Mentone, near Nice, on the Mediterranean, is reported to be that of a person "six feet high, with rather a long but large head, high and well made forehead, and a very large facial angle—85°". Some skeletons found in caves in Belgium were of men less tall, but the skulls were "high and short, and of good Caucassian type, though of medium capacity . . . a fair average human skull," according to Prof. Huxley. A skull of inferior form was found in the Neanderthal Cave, near Dusseldorf. The forehead is low, but the cranial capacity is about seventy-five cubic inches. "This," says Huxley, "is nearly on a level between the two human extremes, and in no sense can the Neanderthal bones be regarded as the remains of a human being intermediate between man and the apes." Such intermediate forms have never been found. "This is the more extraordinary," writes Prof. Dana, "in view of the fact that from the lowest limit in existing men there are all possible gradations up to the highest; while below that limit there is an abrupt fall to the ape level, in which the cubic capacity of the brain is one-half less. If the links ever existed, their annihilation without a relic is so extremely improbable that it may be pronounced impossible. Until some are found, science can not assert that they ever existed." Hence we may conclude that however ancient the earliest human being may

have been, however rude the implements by which he gained his living, or however long the animals contemporaneous with him may have been extinct, he was nevertheless a true man.

"A man's a man for a' that."

229. Since the advent of Man upon the earth many animals have become extinct. Some of these are found with

Fig. 428.

Dodo.

the earliest remains of man. These are extinct species of the elephant, rhinoceros, urus, cave bear, cave hyena,

cave lion, etc. Besides these, many species have become extinct within the Historic Period, some through the agency of Man. The Dutch explorers in the seventeenth century found the *Dodo*—a large, clumsy bird—very abundant on the Mauritius and adjacent islands in the Indian Ocean. It was soon exterminated. It is shown in Fig. 428.

Fig. 429.

Dinornis giganteus.

One fortieth natural size.

Fig. 429 represents the skeleton of the *Dinornis giganteus* from New Zealand. It probably stood twelve feet high. The *Dinornis elephantopus*, although not so tall, had much more massive bones. The *Epiornis* of Madagascar was twelve feet high. Its eggs have been found measuring thirteen inches in length and nine inches in diameter, with a capacity of two gallons.

It is said that the Great Auk (*Alca impennis*), a bird found abundantly along the north-eastern coast of North America in the last century, has disappeared, none having been seen in the last thirty years. The wild turkey is rapidly disappearing in the Interior States, and the American buffalo (*Bos Americanus*), which was once abundant in the same region, has been

driven west of the Missouri, and its range and numbers grow more limited each year. The useful White Pine and Cedar have been well nigh exterminated in many states, and Prof. Asa Gray predicts that the giant *Sequoia*, of California, will become extinct as a native plant, and adds: "Few and evil are the days of all the forests likely to be while man, both barbarian and civilized, torments them with fires fatal at once to seedling and at length to the aged also."

CHAPTER XX.

Progress of Life in the Earth. Theories Explaining It.

230. Progress of Life briefly stated.—It has already been seen that as we descend from the earlier geologic times to the era of man there is a vast progress in life-forms. We obtain the first trace of animal life in the old Laurentian rocks of Canada, in the *Eozoön Canadense.* This represents a low form of animal, but it is said to be not the lowest of its type—not so low, indeed, as many of the Foraminifers now living upon the bottom of the ocean. Plants are believed to have lived in the Laurentian days, since from them doubtless came the carbon of the graphite, so abundant in those old rocks, but no distinct plants have ever been found. Passing by the Huronian beds, which are very thick, and which have as yet yielded no traces of organic life, we find in the old Primordial rocks of the Lower Silurian a remarkable assemblage of fossils, representing the three great departments,—Mollusks, Articulates, and Radiates. The very highest division of the Mollusks is represented in the orthoceratites of the group of Cephalopods, a group which includes the modern nautilus and cuttle-fish. A cuttle-fish, recently thrown alive upon the coast of Newfoundland, is described by Prof. Verrell as being "nine and a half feet long from tip of

tail to base of arms; body, seven feet in circumference, with tentacular arms thirty feet long." The Cephalopods, represented by the orthoceratites of the Lower Silurian, especially in the Trenton rocks, where their shells have been found ten to twelve feet long, were much larger than the monsters now living in the Atlantic Ocean. In the Primordial rocks are trilobites (Articulates) and crinoids (Radiates). Thus we have at the base of the Silurian an assemblage of animal forms of no mean rank in the zoölogical scale.

In Europe, fishes (Vertebrates) have been found in the Upper Silurian, but as yet none have been found in this country, excepting a single specimen reported by Prof. Hall. They are, however, abundant in our Devonian rocks. Some of the earliest known fishes were sharks, a highly organized type of fishes. Some of the modern sharks show an organization of brain which brings them extremely near to reptiles.

In the Carboniferous rocks we have numerous Ganoid fishes, allied to the modern gar-pike of our interior rivers and lakes. An American gar, in a museum in Europe, gave Agassiz his first clue to the structure of the fossil Ganoids. The Teliosts, a class to which most of our modern fishes belong, such as salmon, white-fish, perch, bass, etc., first appeared in the Cretaceous,—the latest division of the Mesozoic Time.

Amphibians appeared in the Carboniferous Age. These rank next above fishes in the zoölogical scale. Some of the early Amphibians "resembled," says Prof. Marsh, "a salamander in shape, while others were serpent-like in form. None of those yet discovered were frog-like or without a tail, although the restored Labyrinthodonts of the text-books are thus represented." The same naturalist regards

the early Amphibians as descended from some earlier member of the Ganoid group of fishes.

True reptiles appeared in force in the Mesozoic Time, and this is called the Age of Reptiles, but a few pioneers of this group appeared in the Permian. Among the earliest of the Mesozoic reptiles are the Dinosaurs (terrible lizards), which show, according to Prof. Marsh, "certain well marked points of resemblance to existing birds of the order of Ratitæ, a group which includes the modern Ostrich, and it is not improbable that they are the parent stock from which birds originated." Reptiles are very abundant in the Cretaceous rocks of the United States, some of which are of immense size. Among these are the flying lizards.

Birds appeared long before snakes. They are found in the Cretaceous rocks of the United States, and a little earlier in Europe.

The earliest serpents yet found, appear in the early Tertiary. One of these, the Titanophis, was thirty feet long.

Mammals, the highest of the Vertebrates, are first found in the Triassic division of the Mesozoic. The forerunners of this great class are small Marsupials, the low type to which the American opossum belongs. Mammals became very abundant in the early Tertiary, and, from that time to the present, they have been the dominant type of life. To this type man belongs. The progress in mammalian life is seen by comparing the two extremes,—the Marsupial on the one hand, and Man on the other, but the details of that progress are not yet fully worked out by the zoölogists, although many very splendid discoveries have been made, and new and important facts are ascertained every year. In some cases, there appears to be such a connection between allied forms as to convince many zoölogists

that there was a direct lineage between the older and later; while in other cases, forms are separated from those gone before by chasms so wide that the genius of Marsh and Huxley can, as yet, find no way to bridge them by any lines of ancestral descent. In anatomical structure the last known link in the series before man is the ape. Apes of a low order are found in the early Eocene of New Mexico, at the base of the Tertiary, but no traces of the higher or more man-like apes have ever been found on the Western Continent.

231. The Theory of Separate and Special Creation.—The late Prof. Agassiz, one of the most eminent of naturalists, held that all animals, excepting those of the very lowest forms, are grouped into a few well marked types or branches,—the Molluscan, the Radiate, the Articulate, and the Vertebrate. These represent so many different plans of structure, just as the Egyptian, the Grecian, and the Gothic represent distinct plans or ideas in architecture. The Creator has, for example, worked out the vertebrate idea in an almost endless variety of mammals, birds, fishes, etc., very much as builders in a former age worked out the Gothic idea, in a thousand ways, in churches, and cathedrals, and abbeys. Each grand type or branch of the Animal Kingdom is set forth in Nature by Classes, Orders, Families, Genera, and Species,—each of these showing a distinct and unvarying form of structure. In the great plan, each species, according to Agassiz, had its appointed place and time, and made its appearance upon the earth by the "direct intervention" of the Creator. The progress of life, therefore, consisted in His introducing from time to time higher forms of animals, with Man, the last and highest of all, at the head. Agassiz earnestly denied that one form of animal could be derived

by any process of development or descent from another form; that by no possibility could a reptile be changed into a bird, or an ape into a man. The progress of life was by a wonderful series of upward steps, each distinct and each expressing a thought of the Creator; and not by an inclined plane on which a vitalized atom or monad climbed upward to man's estate. This theory of distinct creations has been a very common one in the past, and is yet held by many naturalists of great distinction.

232. **The Evolution Theory.**—The other leading theory is that of Evolution, according to which higher forms of animals and plants have been evolved or developed from lower forms. This general theory takes many shapes; indeed, the theory is itself in the process of evolution.

Darwin holds that in all animals and plants there is an inherent tendency to slight changes; and that whenever such a change in any part or organ takes place as gives the animal or plant any advantage in the struggle for existence over others of the same species, that animal or plant thus changed will outlast those less favored. Thus, "a ruminant," says Darwin, "with a slight elongation of neck, or head, or tongue, or fore-limbs, might in a time of dearth have a little advantage, and be enabled to browse on higher twigs, and thus survive. A few mouthfuls, more or less, every day, would make all the difference between life and death. By the repetition of the same process, and by the occasional intercrossing of the survivors, there would be some progress, slow and fluctuating though it would be, towards the admirably coördinated structure of the giraffe," an animal remarkable for its long neck and long fore-legs. (See note on next page.)

"Darwinism" calls for slight variations in the structure of animals and plants, and, when such changes are useful,

the changed form is transmitted by natural descent, and continues for a longer or shorter period. By repeated changes, a new species of the animal or plant is produced and after long lapses of time new genera, and families, and all the higher divisions of animal and vegetable life.

Beginning, therefore, with a few living germs, the earth has been filled with an immense variety of animals and plants, fossil or recent. Nature selects such as are fitted to survive, and preserves them. Hence the term "natural selection," as applied by Darwin to express the process of evolution. Under this process, continued through an almost infinite series of minute changes, man has been evolved from some lowly germ of life which made its appearance in the earliest Palæozoic time.

Nothing, however, is claimed for this theory as involving any *plan* of progress. "One of the principal claims of Mr. Darwin," writes Lyell, an advocate of the theory, "is that it enables us to dispense with a law of progression as a necessary accompaniment of variation. It will account equally well for what is called degradation, or a retrograde movement towards a simpler structure." The variations of animals and plants are in all possible directions, a part tending to progress, and a part towards deterioration. These minute changes are, so far as known, controlled by no law, and are therefore apparently fortuitous or accidental. There have been, so to speak, an al-

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NOTE.—This differs from the old theory of Lamarck, according to which the progenitors of the giraffe, seeking food upon trees above their heads, stretched up their necks and fore-legs, which thus became permanently lengthened. Darwin holds that the lengthening was the result of almost innumerable slight natural changes, and being thus made taller the animal could feed high, and so have an advantage in times of scarcity of food.

most infinite number of throws of Nature's dice (any two consecutive throws, however, differing from each other only by a little,) and the result has been the production of a monad, the lowest throw, and of man, the highest throw, with a vast number of intermediate throws in Mollusks, Radiates, etc., the earth to-day presenting a wonderful commingling of living forms ranging through the whole series. At the same time it must be remembered that these minute changes of animals and plants which have occurred since the beginning of life on the earth, must have fitted into (as a screw fits into a nut) a corresponding series of changes in the external and material conditions of life; else there could be no "survival of the fittest." For example, a slight accidental lengthening of the neck of the giraffe would not help that animal if it lived where only grass and low shrubs grew. Trees and high-growing plants must, therefore, have happened to grow just where the giraffe lived whose neck happened to be elongated. So with all the innumerable variations in animals and plants since the dawn of life, they must have severally fitted into that other series of changes—in heat and cold, dryness and moisture, elevation or depression of lands, the freshening of salt waters, the innumerable modifications in the food supply, and the like, which have ever been taking place in the earth.

If, therefore, there be any progress of life, as the geological record plainly shows, and as the existence of Man, the masterful and crowning being of all, proves, the explanation is to be found in no part of the theory of Darwin, but in the fact that in all this play of seemingly accidental variations, the results show plan and thought, and that thus the Author of nature is working out purposes of the highest significance.

Prof. Asa Gray, so widely known as a botanist and as an earnest defender of the Darwinian theory of evolution, thus eloquently writes: "Let us hope that the religious faith which survived without a shock the notion of the fixity of the earth,* may equally outlast the notion of the absolute fixity of the species which inhabit it; that in the future, even more than in the past, faith in an *order*, which is the basis of science, will not—as it can not reasonably—be dissevered from faith in an *Ordainer*, which is the basis of religion."

It should be stated that Wallace, who equally with Darwin originated the doctrine of "Natural Selection," earnestly denies the applicability of the doctrine to man, and wholly repudiates the lineage of man from the ape. According to the theory, only that variety of form survives which is useful. The earliest savages, for example, had little use for the large brain they possessed. Savages make little use of the musical faculty, and yet they possess all the needed organs for the production of the sweetest music. The same naturalist is unable to see how by "natural selection" the hair on the back of the ape, so useful to that animal, would have been less useful to the early man, and yet the rudest savages are without it. The origin of the mental faculties of man he finds even more difficult of explanation upon the evolution theory, while the theory utterly breaks down in accounting for man's higher moral and spiritual faculties. It should be added, that with all lower animals the stronger survive and the weaker perish, but man is under the dominion of a different principle. He builds hospitals for the sick, and asylums for

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* NOTE.—Before the time of Galileo, the earth was thought to be fixed, and the sun was believed to revolve around it.

the blind, the deaf, the demented, and the idiot. In the Interior States these unfortunate classes live in palaces at the expense of the people.

233. **Mivart's Theory of Evolution.**—This eminent British naturalist holds to the doctrine of variations, but the variations are large and sudden. Such great changes of form are not uncommon in domesticated animals, in dogs, barn-yard fowls, pigeons, etc. He states in the *Genesis of Species* that "there are abundant evidences to prove that considerable modifications may suddenly develop themselves. . . . Moreover these modifications, from whatever cause arising, are capable of reproduction, the modified individuals 'breeding true.'" He gives a most interesting illustration in the case of the hand of the Potto, one of the lower forms of monkeys, in which the forefinger is gone. The hand is shown in Fig. 430. According to the Darwinian theory, the forefinger was lost by a series of slight and long-continued modifications which were useful to the animal. Such a loss, Mivart argues, would rather be a serious injury, and it could only take place by a sudden change corresponding to a freak in Nature, and the loss, once sustained, became permanent.

Fig. 430.

Hand of Potto.

The same naturalist adduces the well known case of the flounder and allied fishes, which have both eyes on one side of the head. The head of such a fish is shown in Fig. 431, page 266. It appears to be a strange sport in Nature, which has perpetuated itself in the descendants of the first fish or fishes in which it appeared. It adds much to the strangeness of this class of fishes to learn that, when

young, the eyes are situated, as in other fishes, one on each side of the head, but afterwards one eye traveled over the nose to a position not very far from the other. All this appears very preposterous, but yet it is a transmitted feature in all this class of fishes.

Fig. 431.

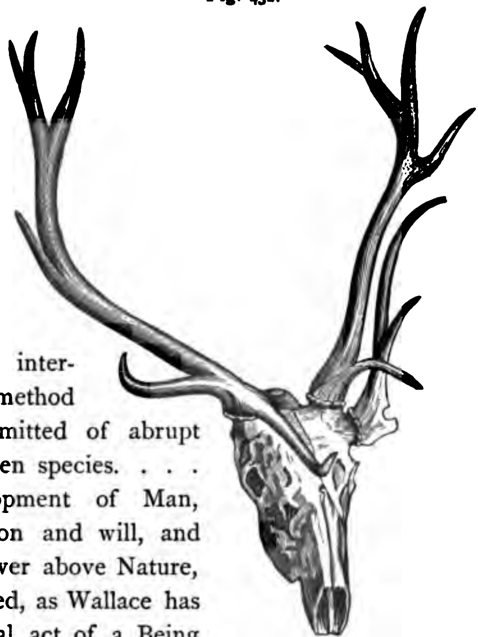
Pleuronectes maculatus.

There are doubtless many instances of such curious variations in animal forms. In Fig. 432 we have the head of an elk, brought by the author from the upper Missouri, on which grew three distinct horns, two on one side of the head. There is, of course, no proof that this peculiarity has been transmitted to offspring. There is, indeed, always a tendency to a return to the original form. This reversion, as it is called, may not take place for several generations, and, indeed, it may never take place, the new variety remaining a permanent one; in which case, according to Mivart, we have a new species. He asserts that "these 'jumps' are considerable in comparison with the minute variations of 'Natural Selection,'—are, in fact, sensible steps, such as discriminate species from species." He admits that the causes of these sudden and marked changes of structure are for the most part "unknown." These "jumps" of Mivart, which are in themselves inexplicable, like the minute variations of Darwin, nevertheless make for order and progress, and Mivart, equally with Gray, believes in a Divine Ordainer. The changes in animals and plants are brought about by natural laws, however obscure they may be, and not by a special supernatural agency: "These laws," says Mivart, "acting with the divine concurrence, and in obedience to a creative fiat originally imposed upon

the primeval cosmos in the beginning by its Creator, its Upholder, and its Lord."

Prof. Dana states as conclusions "most likely to be sustained by future research," that "the evolution of the system of life went forward through the derivation of species from species, according to natural methods not yet clearly understood, and with few occasions for supernatural intervention. This method of evolution admitted of abrupt transitions between species. . . . For the development of Man, gifted with reason and will, and thus made a power above Nature, there was required, as Wallace has urged, the special act of a Being above Nature, whose supreme will is not only the source of natural law but the working force of Nature herself." Agassiz held to abrupt transitions between species, and that each species was introduced by a special act of the Creator. It is urged against the doctrine of special creation that it explains nothing, and therefore has no scientific value. If, on the other hand, evolution introduces new species through natural laws as yet "unknown," and by "natural methods not yet clearly

Fig. 432.



Head of Elk.

understood," it is evident that the whole question is still involved in much obscurity.

The evolution theory has great value as a working hypothesis, and is very stimulating to the naturalist who wishes to know how animals and plants came to be. As the philosophic historian eagerly investigates the lines of the descent of nations and of famous men, so the naturalist and geologist as earnestly desire to know the genealogy of all living forms which have appeared and disappeared in the earth. This study of lineage has already led to important discoveries.

Every theory of evolution must have its starting point in some created living germ or germs. No way has yet been found by which the chasm between the non-living and the living may be bridged. The very careful experiments of Tyndall show that a living germ must be present in all cases before there can be any manifestation of life, and science failing to discover the origin of life, leaves us to the conclusion that it was a divine creation.

Let us furthermore believe that that Being who created the first beginnings of life, and who surely created Man at the summit of the scale to be His image-bearer—a thinker and a ruler on the earth, has never been unmindful of the intermediate stages, but has rather impressed Himself upon the whole series. We may not now know all the methods of His workings in Nature, but science is slowly feeling the way to firm ground, upon which we may safely rest.

It is not uncommon in text books on Geology to consider the relations between the Biblical and Geological records. The author of this volume will omit this. The Bible record, especially the Book of Genesis, is very far from being definitely made out by biblical students, while

on the other hand the geologists have as yet studied but imperfectly the pages of the great stone volume, and there are doubtless missing leaves yet to be recovered. The work of investigation must still go on; and the student of each record, seeking the truth "in the love of it," should be glad that there are such inviting fields of research before him. For the geologist we may, at least, speak:

"My spirit bows in gratitude
Before the Giver of all good,
Who fashioned so the human mind,
That, from the waste of Time behind
A simple stone or mound of earth
Can summon the departed forth;
Quicken the Past to life again—
The Present lose in what hath been,
And in their primal freshness show
The buried forms of long ago."

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